San Joaquin River National Wildlife Refuge
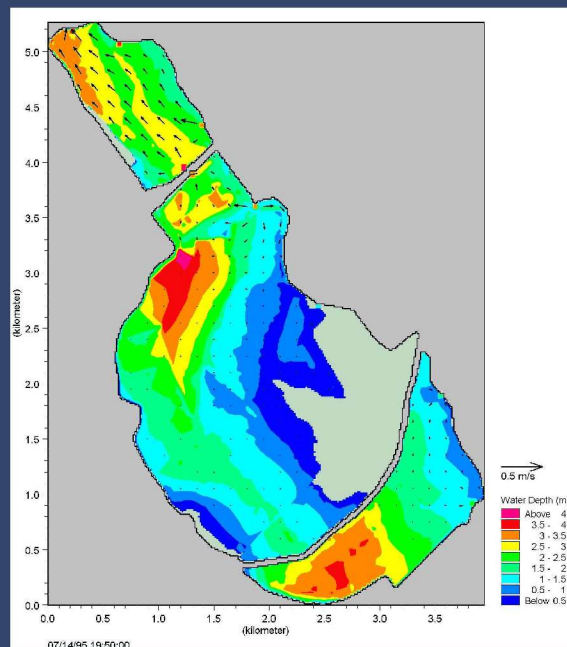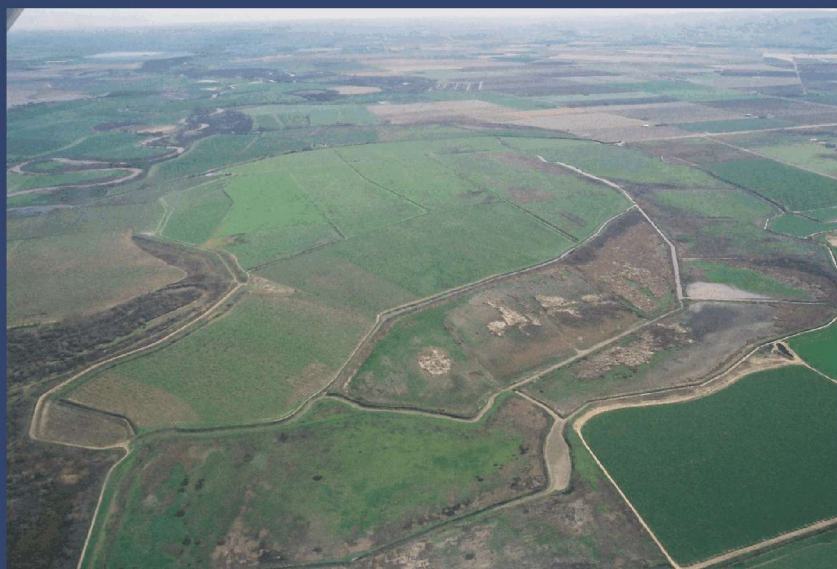## *Phase 2: Habitat Implications of Levee Breaching Alternatives*

Prepared for

US Fish & Wildlife Service

PWA

PHILIP WILLIAMS & ASSOCIATES, LTD.

SAN JOAQUIN RIVER NATIONAL WILDLIFE REFUGE
PHASE 2: HABITAT IMPLICATIONS OF
LEVEE BREACH ALTERNATIVES

Prepared for

Ducks Unlimited, Inc.

and

United States Fish and Wildlife Service
Anadromous Fish Restoration Program

Prepared by

Philip Williams & Associates, Ltd.

October 2004

PWA REF. # 1568.00

October 29, 2004

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Ducks Unlimited
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Anadromous Fish Restoration Program
4001 N. Wilson Way
Stockton, CA 95205

RE: **San Joaquin River National River National Wildlife Refuge – Phase 2**
    PWA Ref. # 1568.00

Dear Jim:

Attached is the Final Report for Phase 2 of the San Joaquin River National Wildlife Refuge Floodplain Restoration Project. Phase 1 of the project developed an hydraulic model of the non-structural flood management alternative proposed by the US Army Corps of Engineers in 1998. We submitted our Phase 1 report to you in May 2001. In Phase 2 of the project, described in this report, we developed and analyzed the relative habitat benefits for anadromous fish of alternative versions of the original concept using a refined hydraulic model.

I am pleased to report that our analysis in Phase 2 highlighted the differences in floodplain function between levee breaching alternatives. We assessed and compared the potential effect on anadromous fish habitat for each alternative using the evaluation criteria developed in Phase 1 and demonstrated that minor refinement of the original non-structural alternative has the potential to benefit habitat conditions. We found that providing for connections across the three component properties has the potential to improve the dynamic interaction of the river and the floodplain as well as improving flow over the floodplain.

We have thoroughly enjoyed working with the staff of Ducks Unlimited, the US Fish and Wildlife Service National Wildlife Refuge and the Anadromous Fish Restoration Program on this important project to reconnect and restore California's frequently-inundated floodplain habitat, a critical component of riverine ecosystem function. If there is anything else we can do to assist you, please do not hesitate to contact us.

Sincerely,
PHILIP WILLIAMS & ASSOCIATES, LTD.

Elizabeth S. Andrews, P.E., Principal
Project Director

Services provided pursuant to this Agreement are intended solely for the use and benefit of Ducks Unlimited Inc., and the U.S. Fish and Wildlife Service.

No other person or entity shall be entitled to rely on the services, opinions, recommendations, plans or specifications provided pursuant to this agreement without the express written consent of Philip Williams & Associates, Ltd., 720 California Street, 6th Floor, San Francisco, CA 94108.

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04/02/04

1. INTRODUCTION

1.1 CONTEXT AND RATIONALE FOR THE STUDY

As a result of the January 1997 flood, several levees failed along the west side of the San Joaquin River in the vicinity of the Tuolumne River confluence. After the flood, the levees were repaired; however, the San Joaquin River National Wildlife Refuge (SJRNWR) worked with the US Army Corps of Engineers (USACE) to plan a non-structural flood management alternative (NSA) to reduce future flood hazards along a reach that was both subject to flood failure and planned for flooding-compatible uses. This alternative includes breaching existing mainstem San Joaquin River levees on recently acquired SJRNWR land to protect and restore wetland and riparian habitat. The proposed NSA will provide floodplain inundation behind project levees of up to 3,100 acres of SJRNWR land in some years.

The focus of Phase 1 of this study, completed in May 2001 (PWA) was to develop the tools to evaluate habitat effects of proposed levee breaches and modifications to the proposed levee breaches (referred to as "NSA refinements") with particular emphasis on anadromous fish. The primary analysis tool used in this study was a one-dimensional, looped network hydrodynamic model, MIKE 11. Model results generated include depth and time of inundation as well as simulated flow during a sample flood on reactivated floodplain at the SJRNWR.

The focus of this Phase 2 of the study was to develop and analyze alternatives to the original USACE non-structural alternative and relate the results of the analysis to the habitat evaluation criteria developed in Phase 1 of the study. The goal of Phase 2 was to identify a preferred alternative for levee breaching at the SJRNWR that integrates improved floodplain habitat to benefit anadromous fish, to complement existing aquatic and terrestrial habitat consistent with local infrastructure goals and requirements. The primary analysis tool used in Phase 2 of the study was a one-dimensional, looped network hydrodynamic model, MIKE 11, which was dynamically coupled to a two-dimensional, depth averaged hydrodynamic model, MIKE 21. The resulting modeling package is referred to as MIKE FLOOD. In this instance, MIKE 11 was used to model the main channel of the San Joaquin River and associated floodplains within the project levees while MIKE 21 was used to model the floodplain units of the SJRNWR. The MIKE FLOOD package provided for the integration of these two modeling tools in a single modeling environment.

Philip Williams & Associates, Ltd. (PWA) undertook the study under contract to Ducks Unlimited (DU) on behalf of the U. S. Fish and Wildlife Service (USFWS) Anadromous Fish Restoration Program (AFRP). Funding for the current study was provided by the AFRP.

This report describes the setting of the site, the hydrodynamic modeling methodology, the modeling results evaluation and physical process input into the post-project monitoring plan. The modeling results are evaluated based on the habitat criteria established in Phase 1 with the exception of inundation timing, as timing is driven by the San Joaquin River's flow regime and does not vary significantly between the

alternatives. The habitat criteria applied include frequency, duration, depth and area of flooding; potential for fish stranding; and potential for creation of non-native or predator fish species habitat.

1.2   STUDY OBJECTIVES

The objectives of the current study are defined as:

1. The analysis and evaluation of alternatives for levee breaching in terms of habitat evaluation criteria developed in Phase 1 of the study.
2. The recommendation of a preferred alternative for levee breaching.
3. The development of physical process input into the post-project monitoring plan.

1.3   INTENDED USE OF THIS STUDY

Phase 1 of the study represented an initial overview of the proposed non-structural flood management alternative proposed by the USACE. Refinements to the proposed alternative were evaluated in Phase 2 (this study) of the project. The results contained in this report represent the potential conditions of the SJNWR under the proposed seasonal wetland design as defined by the SJNWR. Modifications to the seasonal wetland designs may alter the results described in this report.

The modeling described in this report was undertaken for the purposes of evaluation of alternatives and recommendation of a preferred alternative. It is not intended to be used for final design of a preferred alternative.

2. FINDINGS AND RECOMMENDATIONS

This section presents key findings and recommendations, which are described and supported in the remainder of the report.

Our analysis examined three alternative scenarios for levee breaches affecting the floodplains outside the project levees at the SJRNWR (i.e. the Lara, Hagemann, and Vierra Properties). The alternatives evaluated in this study can be summarized as follows:

1. Alternative 1 (base condition NSA): Lara, Hagemann and Vierra function independently as three separate floodplains with separate breaches through the project levee to the San Joaquin River. One ineffective proposed NSA breach was eliminated and another was moved based on the findings of Phase 1 study. Alternative 1 is the baseline condition for comparison to Alternatives 2 and 3.

2. Alternative 2: Flow-through connectivity is provided between Lara, Hagemann and Vierra through openings in the berms along West Stanislaus Canal and levees on Hospital Creek.

3. Alternative 3: An opening in the levee along Hospital Creek provides connectivity between Vierra and Hagemann during flood flows. Lara continues to function independently.

2.1   FINDINGS

1. Generally, Lara floods at about 8,500 cfs and Vierra at about 11,000 cfs. The Hagemann flooding threshold varies between alternatives (10,900 cfs – 13,800 cfs). These flows correlate approximately to between a 2- and 3-year event if breaches are made as proposed in the NSA and are cut to the depth of the adjoining ground elevation of the floodplain. This frequency of new floodplain area inundation is sufficient to regularly increase the availability of spawning habitat for splittail and rearing habitat for splittail and Chinook salmon, as well as providing other habitat benefits.

2. Alternative 2 provides more positive flooding/draining than the other two alternatives.

3. The most active breaches are 1) 1, 6, 7, West Stanislaus Canal-north, Hospital Creek-north for flooding and 2) 2, West Stanislaus Canal-south, Hospital Creek-south, and 8 for draining. Breach 5 acts as both draining/flooding, but is not as efficient as any of the other breaches. Breach 2 acts primarily as a drain in Alternatives 1 and 3, but in Alternative 2 provides a lesser draining function. Breach 4 provides very little flooding or draining function during the modeled minor flooding event.

4. The elevation of most of the SJRNWR floodplain is lower than the elevation of the breaches, as currently configured and modeled in this study, due to the presence of natural levees underlying

the project levees of the San Joaquin River. It is possible that this configuration may result in significant ponding on the floodplain, as low elevation drainage will not occur through the breaches themselves. Model simulations suggest that during a minor flood similar to the event modeled in this study, the depth of ponding could range from 0 to 4 feet on the floodplain, excluding canals and ditches. Existing infrastructure maintained by the SJRNWR is likely capable of ensuring adequate drainage to minimize fish stranding after flood events. However, final design of the preferred alternative should carefully consider the issue of fish stranding and existing or improved means to drain the floodplain adequately.

5. Alternative 1 will result in a frequency of flooding approximately every 2.0 to 2.7 years, with peak inundation areas during the modeled flood of approximately 2,200 acres and maximum depths between approximately of 4 and 14 feet depending on location on the floodplain. Velocity magnitudes on the floodplain vary from approximately 0 ft/s to 4.6 ft/s. Maximum modeled flows into the floodplain vary between the parcels: 350 cfs into Lara, 1,410 cfs into Hagemann and 5,470 cfs into Vierra.

6. Model results for Alternative 2 indicate that flooding on Hagemann will occur more frequently than with Alternative 1. The area and duration of flooding will also be greater with Alternative 2. Alternative 2 has a peak inundation area during the modeled flood of approximately 1,900 acres and maximum depths ranging from 2 to 14 feet across the SJRNWR. Velocity magnitudes vary from 0 to 4.6 f/s. Maximum modeled floodplain inflows to each parcel are 1,020 cfs into Lara, 3,460 cfs into Hagemann, and 6,070 cfs into Vierra, a significant increase over Alternative 1. Increased inflows over Alternative 1 are evidence of the through-flow connection between the parcels. Inflows to Hagemann through the West Stanislaus Canal breach originate as outflows from Lara and similarly, inflows to Vierra across Hospital Creek are outflows from Hagemann.

7. Alternative 3 behaves similarly to Alternative 1, with slightly greater flood depths and durations, and improved draining on Hagemann via the Hospital Creek breach (Hospital Creek-south).

8. It unlikely that any of the alternatives will have a downstream flood impact. The modeling results indicate that in fact a small degree of attenuation of flows occurs for all alternatives, which will slightly reduce flood impacts locally. However, the magnitude of this attenuation is negligible and should not be considered a significant benefit of the project.

9. Alternative 2 provides for the greatest attenuation of flows from the San Joaquin River, though the stage reduction is relatively minor at 0.3 feet.

10. The breaches on Lara are highly beneficial for floodplain inundation since Lara inundates at the lowest recurrence interval flow (2.0-year). Therefore, it is likely that Lara will be the most frequently used floodplain habitat and future restoration activities should recognize this expectation.

11. Alternative 2 is slightly more preferable in terms of more frequent floodplain inundation, though this benefit occurs primarily only on Hagemann.

12. For total area of inundation for depths between six inches and six feet, Alternative 1 provides the largest area, closely followed by Alternative 2; however, Alternative 2 provides a longer duration of inundation.

13. In Alternative 3, Hospital Creek, and in Alternative 2, the West Stanislaus Canal and Hospital Creek, contribute significantly to water and sediment fluxes between the river and floodplain.

14. For the modeled flood, velocities on the floodplain, and hence through-flows on the floodplain, are most likely to minimize fish stranding in Alternative 2. Fish stranding issues may be least problematic in Vierra where beneficial flow-through velocities are maintained in all alternatives. Hagemann tends to behave as a backwater in Alternative 1 and therefore would be most susceptible to fish stranding issues. Lara behaves similarly as a backwater in Alternatives 1 and 3, although not to the same extent as Hagemann.

15. Alternative 2 may have the greatest impact to the West Stanislaus Canal in terms of altering the flow regime in the canal during flood events. In terms of positive benefits, the altered flow regime in the canal under Alternative 2 may provide for increased scour potential in the canal during flood events, particularly in the receding limb of the hydrograph.

2.2   RECOMMENDATIONS

1. For the purposes of enhancing ecosystem function, Alternative 2 is recommended over Alternatives 1 and 3, because it has the highest expected level of dynamic interaction between the river and floodplain, the highest potential habitat value for anadromous fish, and the least potential for fish stranding. The addition of breaches across West Stanislaus Canal dramatically increases inundation and flow-through velocities on Hagemann, the largest of the three SJRNWR floodplain parcels Overall, flood depth, duration and area are slightly greater for Alternative 2 under the modeled flood than for Alternatives 1 and 3. In addition, West Stanislaus Canal levees are not engineered levees—they are constructed of canal dredge material—and may fail under the flood flows that will occur once the project levees have been breached. The apparent ecosystem benefits of Alternative 2 will have to be evaluated relative to any potential concerns regarding the reintroduction of full flood dynamics to the West Stanislaus Canal and lower Hospital Creek.

2. Passive outlet drainage should be constructed for the primary irrigation canal on each floodplain parcel. Each of the three floodplain parcels drains to a single outlet currently. However, in order to provide complete drainage of each floodplain, water is currently pumped out of the SJRNWR to the San Joaquin River. Outlets should be designed and constructed to allow passive drainage to the San Joaquin River, without the use of pumps. These outlets should be constructed at Breach 5, Breach 7, and at the West Stanislaus Canal-south breach location.

3. Physical process monitoring is a valuable component for future site management and to maximize the knowledge gained from implementation of this project, though it may require considerable investment. The goals of physical process monitoring may include characterizing the physical processes associated with habitat conditions for the purposes of gauging the benefits and success of the project, providing a basis for adjusting site management, and describing the geomorphic evolution of the site. The physical parameters to be monitored may include depth, duration, timing, velocity, flow patterns, ponding and temperature of surface water flow, and groundwater elevation. More intensive monitoring is proposed in the first 5 to 10 years of site evolution with a total monitoring timeline of 50 years. The average annual cost of proposed monitoring is approximately $20,500 over 50 years, excluding inflation. A reduced monitoring effort, with a corresponding reduction in data, could be achieved for approximately $12,000/year over 50 years.

4. The hydrodynamic model constructed for this study could be used in conjunction with monitoring results as an adaptive management tool to test potential modifications of site function to better meet project goals and objectives.

3. SETTING

3.1   PROJECT SITE

The SJRNWR is located on the San Joaquin River downstream of the confluence of the San Joaquin and Tuolumne rivers, approximately 9 miles west of the city of Modesto. Levee breach sites identified in the NSA plan prepared by the USACE are located on the San Joaquin River from approximately River Mile (RM) 79 to RM 86.   Three Reclamation District levees are proposed for modification within the SJRNWR. A map of the site is shown in Figure 3-1. Two photographs showing aerial views of the site are provided in Figure 3-2 and Figure 3-3.

3.2   SITE HISTORY

3.2.1   <u>Historic</u> <u>Land</u> <u>Use</u>

The SJRNWR has historically been used for livestock grazing and cultivated agriculture including orchard and row crops. Agricultural development and channel alterations in the SJRNWR are evident in documents from the early 1900's. In 1926, the West Stanislaus Irrigation District developed a canal system that included a diversion at the site of the SJRNWR. Irrigation systems on SJRNWR lands were also constructed at about this time (Griggs, 2000).

3.2.2   <u>Purchase</u> <u>of</u> <u>Study</u> <u>Site</u>

In 1999, the USFWS purchased 3,166 acres of flood-prone farmland consisting of three properties located on the west bank of the San Joaquin River between RM 77 and RM 84, near the confluence of the Tuolumne River with the San Joaquin River. Levees protecting these parcels had failed in 1983 and 1997. One of the principal reasons for the purchase of the land, which became a significant portion of the West Unit of the SJRNWR, was to provide a demonstration of a non-structural flood management alternative. Plans for the site include breaching of levees to allow floodwaters from the river to spread over its former floodplain. It is intended that such levee breaches could relieve pressure on the other local levees as well as surrounding communities during high flows.

3.2.3   <u>Non-Structural</u> <u>Alternative</u> <u>for</u> <u>Flood</u> <u>Control</u>

In February 1998, the USACE, USFWS and the Reclamation Board (RCB) signed an outline of issues and preliminary agreements regarding a non-structural flood control alternative. In this agreement, the USACE provided recommendations to the RCB and USFWS for breaching of levees at the seven locations shown in Figure 3-1, basing their recommendation on a one-dimensional steady-state hydraulic analysis of the expected flood impacts of the proposed breaches through the project reach using the HEC-RAS numerical model. The study analyzed conditions for the design flood of 46,000 cfs, approximately a 60-year flood. The project design profile allows a 3-foot allowance for freeboard. Results of the USACE study are summarized in Table 3-1.

The USACE proposed seven breach locations as shown earlier in Figure 3-1, two locations in each of the levee systems of RD's 2099 and 2102 and three locations in the levees of RD 2100. Breach locations were chosen at known structurally weak areas of the project levees and at topographically low areas along the line of the project levees.

Table 3-1 Results of the USACE Non-Structural Alternative analysis (USACE, 1998)

Property	Area (Acres)	Floodplain Elevation (Feet)	Project Levee Crown (Feet)	Project Flood Water Surface Elevation (Feet)	Area Inundated (Acres)
Vierra	530	20.0 to 25.0	40.5 to 41.5	37.0 to 38.5	530 Complete inundation of district. Occasional inundation to adjacent properties.
Hagemann	1,535	20.0 to 40.0	41.0 to 43.5	38.0 to 40.5	1,535 Complete inundation of district. Minor inundation (15 acres) to adjacent properties.
Lara	400	30.0 to 40.0	43.5 to 46.0	40.5 to 42.3	400 Complete inundation of district. No inundation to adjacent landowners.

3.2.4   San Joaquin River National Wildlife Refuge Phase 1: Analysis of Proposed Levee Breaches

In May 2001, PWA completed Phase 1 of the present study. The objectives of Phase 1 were:

1. To identify apply the hydrodynamics model MIKE11 to simulate flow on SJRNWR floodplains to analyze proposed non-structural alternatives for flood management.
2. To identify areas on the SJRNWR that will be inundated during flood events.
3. To recommend potential modifications to the proposed non-structural alternative for flood management.
4. To develop habitat evaluation criteria to relate parameters describing floodplain inundation to potential benefits and constraints for habitat restoration with particular emphasis on anadromous fish.

The recommendations made in Phase 1 of the study were implemented in this Phase 2 of the study.

A summary of the findings of Phase 1 of the study is given in Section 2 of this report.

3.3   FLOODING AND GEOMORPHIC SETTING

3.3.1   Flood Setting

Precipitation in the San Joaquin Valley occurs primarily from November to April with very little precipitation occurring during summer months. Snow pack accumulates on the east side of the basin above an elevation of about 5,000 feet; snowmelt generally begins to affect runoff by April. Two types of floods may be identified in the basin: rainfall floods during late fall and winter and snowmelt floods during spring and summer. Highest peak discharges are due to floods driven by rainfall runoff; however their duration tends to be lower than floods driven by snowmelt.

Prior to construction of Friant Dam, very high late spring and early summer flows declined gradually over summer to reach minimum flow levels in the fall and early winter.   Today, the system is highly regulated by storage reservoirs, and is further affected by groundwater withdrawals, diversions for irrigation, power, municipal supply, and imported water. During summer months, base flow is low, and consists mainly of return water from irrigated areas. In winter and early spring, higher flows still occur; however, levees currently prevent most of the SJRNWR from flooding. Channel design flow at Maze Road Bridge is 46,000 cfs. However, levees begin to fail, or are overtopped, when flows exceed 40,000 cfs. Out of channel flows may have occurred in 1938 (41,600 cfs), and did occur in 1969 (41,800 cfs), 1983 (38,400 cfs), and 1997 (59,300 cfs) (USACE, 2000).

3.3.2   Geomorphic Setting

As described in Mussetter (2000), the San Joaquin River occupies the southern portion of the Great Central Valley, which is a synclinal trough whose axis is offset to the west side of the basin. The San Joaquin River lies between the crests of the Sierra Nevada and the Coast Range and the basin lies within parts of the Sierra Nevada, California Coast Range and the Great Central Valley geomorphic provinces. The Sierra Nevada is composed primarily of crystalline igneous rocks (granite, quartz monzonite, quartz diorite) with some metamorphic, volcanic, and metavolcanic rocks. The Coast Range is composed of folded and faulted sedimentary rocks. The valley floor is underlain by relatively unconsolidated sediments.

The San Joaquin River is a highly sinuous meandering river system throughout its course. The morphology of the river between the foothills and the delta are controlled by the tectonic uplift of the Sierra Nevada range, subsidence of the San Joaquin Valley, and surface erosion of the watershed. Tectonically-driven subsidence rates are approximately 0.25 mm/yr, and this subsidence is partially counterbalanced by sediment deposition of alluvial fans from the San Joaquin River and tributaries draining from the Sierra Nevada and Coast Range (Janda 1965). Stream gradient is very low in all reaches, with steeper reaches in the foothills less than 0.1 percent, and remaining reaches less than 0.05 percent. Below the Friant Dam, the channel bed material consists of sand.

The geomorphology of the San Joaquin River has changed significantly over the last century due to dramatic changes in hydrologic and sedimentologic conditions. River engineering projects, including dams, bypasses, levee construction, and bank protection, have reduced the magnitude and frequency of flood peaks, increased the magnitude and frequency of the lower flows and increased the magnitude and duration of the moderate flows. In terms of sediment, channelization and levee construction coupled with dam construction have resulted in increased stage, sediment starvation, and elimination of overbank (floodplain) sediment storage space. Channel-floodplain connectivity, which is a critical component of a healthy river system, has been eliminated in most places. The changing sediment dynamics have induced incision and channel degradation throughout the river. Finer bed and bank material caused by changes in hydrology and sediment, lower mean and peak discharges, and more revetment and imposed flow control resulted in low channel migration rates. Recent groundwater pumping has rapidly increased the natural subsidence rate (Bull and Miller 1975), with the elevations of some areas west of Mendota decreasing by over 25 feet. A recent survey and analysis by the USACE (2002) concurs that significant subsidence has occurred in the San Joaquin Valley upstream of the project site, and suggests that as a result, project levees in some areas may currently be up to 17 +/- feet lower than necessary to contain the flow. Continued subsidence is projected to affect up to 240 miles of the San Joaquin system over the next 50 years.

In their classification of floodplains, Nanson and Croke (1992) identified different types of floodplains, defined according to specific stream power at bankfull flow and sediment texture, in which the relative importance of lateral and vertical accretion varies. The San Joaquin River is a medium-energy non-cohesive floodplain, whose specific stream power ranges between 10-300 Watt/m^2. In their natural state, these floodplains are considered to be in dynamic equilibrium with the decadal hydrologic regime and are not usually affected by extreme events over the long-term. The preferred mechanism of floodplain construction is by lateral point-bar accretion. However, floodplain topography also includes numerous features besides layers of fine sediment deposited by overbank flows including splay deposition and avulsion mechanisms. Along the project reach, the specific stream power for bankfull flow conditions ranges between 15 to 50 Watt/m^2. This range is classified as a lateral migration-type floodplain where cut-bank erosion, lateral point-bar accretion, overbank vertical and abandoned-channel accretion processes dominate.

PWA obtained two historic topographic maps of the project site: 1915 and 1930 (USGS and California Debris Commission maps from 1914-15, as updated by the State of California in 1930, respectively), as shown in Figure 3-4. Together with the current USGS map from 1994 (reflects 1978 aerial photo source update; also checked against 1991 data), these sequential topographic maps of the project area illustrate the change in channel/floodplain morphology over the last century. Pre-disturbance, the San Joaquin River through the project reach was a highly sinuous single-braid river with rapid channel migration and surrounded by an extensive floodplain (1915 map). This created a rich complex of oxbow lakes, backwater sloughs, ponds, and sand bars in a mosaic of successional states. Figure 3-4 shows the numerous abandoned channel, meander cutoffs, oxbows, and backwater sloughs on the floodplain. The river formed low natural levees in its lower reaches approximately six feet high (Thompson 1957, Atwater and Belknap 1980); these are evident in the project site cross sections provided as part of the 1930 topography.

The map identified as the 1930 topographic map shows an earlier survey by the California Debris Commission (1914-1915) updated in 1930 by the State of California. The 1930 map shows in its background the broad riparian forests, wetlands, and marshes present at the time of the survey, as well as the early influence of agriculture (e.g., berms, ditches, roads).

Changes in the river form are apparent (see, for example, the changed shape of the bend near the mouth of the West Stanislaus Canal, between the Hagemann and Vierra properties in the center and south, respectively, on Figure 3-4). The 1930 map also identifies the main San Joaquin river channel downstream of Finnegan's cutoff as "Old Channel" and the growth in the width of Finnegan's cutoff since the 1915 map also suggests that it had indeed become the primary channel occupied by the river by 1930. The portion of Finnegan's cutoff north of Maze Boulevard also appears to have been disconnected from the river by 1930, with all flow moving west to the main river channel through what was then called Amphir Cut.

Differences in the size and shape of Upper and Lower White Lake between the 1915 and 1930 maps are also clear. It is interesting that both 1929 and 1930 were dry years in the San Joaquin basin, and possible that the larger size of these features on the 1930 map compared to the 1915 map is the result of the higher stage and/or reduced drainage that would have been caused by the berms or levees also visible on the 1930 map, though differences in the season of the mapping may be a more significant cause.

It is also apparent in the detail available from this map (see Figure 3-5 to Figure 3-7 for larger scale reproductions of the 1930 map shown in Figure 3-4) that in addition to a connection between them, both Upper and Lower White Lake historically had multiple connections: two to the San Joaquin River for the former, and to the river and Hospital Creek for the latter, suggesting upstream flooding and downstream drainage. This difference in water levels would have resulted from the gradient in the San Joaquin River, accentuated by its sinuous course.

The 1994 topographic map shows the significant changes in the channel form and pattern. The most significant change is the abandonment of the main channel through the middle portion of the project reach, with a huge decrease in the riparian zone, and the occupation of the Finnegan Cutoff as the main flow path between the Tuolumne River confluence and Maze Boulevard. The map also illustrates that the channel has been simplified to a single-braid channel with reduced floodplain connectivity and sinuosity. Remnants of complex floodplain topography are still apparent on the map. However, the channel is currently fixed in place by levees and infrastructure and no longer interacts with its floodplain.

Breaching the levees along the project site and reconnecting the channel to its floodplain will restore floodplain function and thus geomorphic and ecologic conditions. Re-establishment of floodplain inundation will result in the re-occupation of backwater sloughs and oxbows and will promote regeneration of riparian forests, provision of seasonal habitat for fish, waterfowl, and other wildlife, and reduced channel degradation through the project reach and downstream. As shown on Figure 3-4, the proposed breach locations are almost entirely located at prior locations of connection between the river and floodplain. Breach 6, the third breach to the south, and Breach 4, located at the site of a 1997 levee

breach, are the sole exceptions. Both are in very close proximity to the historic river channel, however, and will be able to significantly improve flow to parts of the floodplain that would otherwise primarily experience backwater conditions. In addition, both will provide critical connectivity in the event that through-flows across West Stanislaus Canal and Hospital Creek are not available.

N

0   2,000   4,000
feet

121° 14' 11"
37° 38' 37"

Maze Road

Vierra
North

Vierra
South
RD 2099

7

6

5

Hagemann
North

4

SJW20

3

LON 121°12' 00"
LAT 37° 36' 01"

RD 2100

2

Hagemann
South

Lara
East

RD 2102

1

Lara West

area of
detail

Modesto

San Joaquin NWR loc map.cdr

○ = Proposed Breach Location (1998)

● = 1997 Breach

37° 33' 27"
121° 08' 59"

PWA

figure **3-1**

San Joaquin River National Wildlife Refuge – Phase 2
Map of project site

PWA #: 1568

PWA

Labels on image: Vierra, Hagemann, Lara

Source: J. Haas, March 2004.
Notes: Viewed from the south looking north.

figure **3-2**

San Joaquin River National Wildlife Refuge – Phase 2
Aerial photograph of the project site

PWA #: 1568
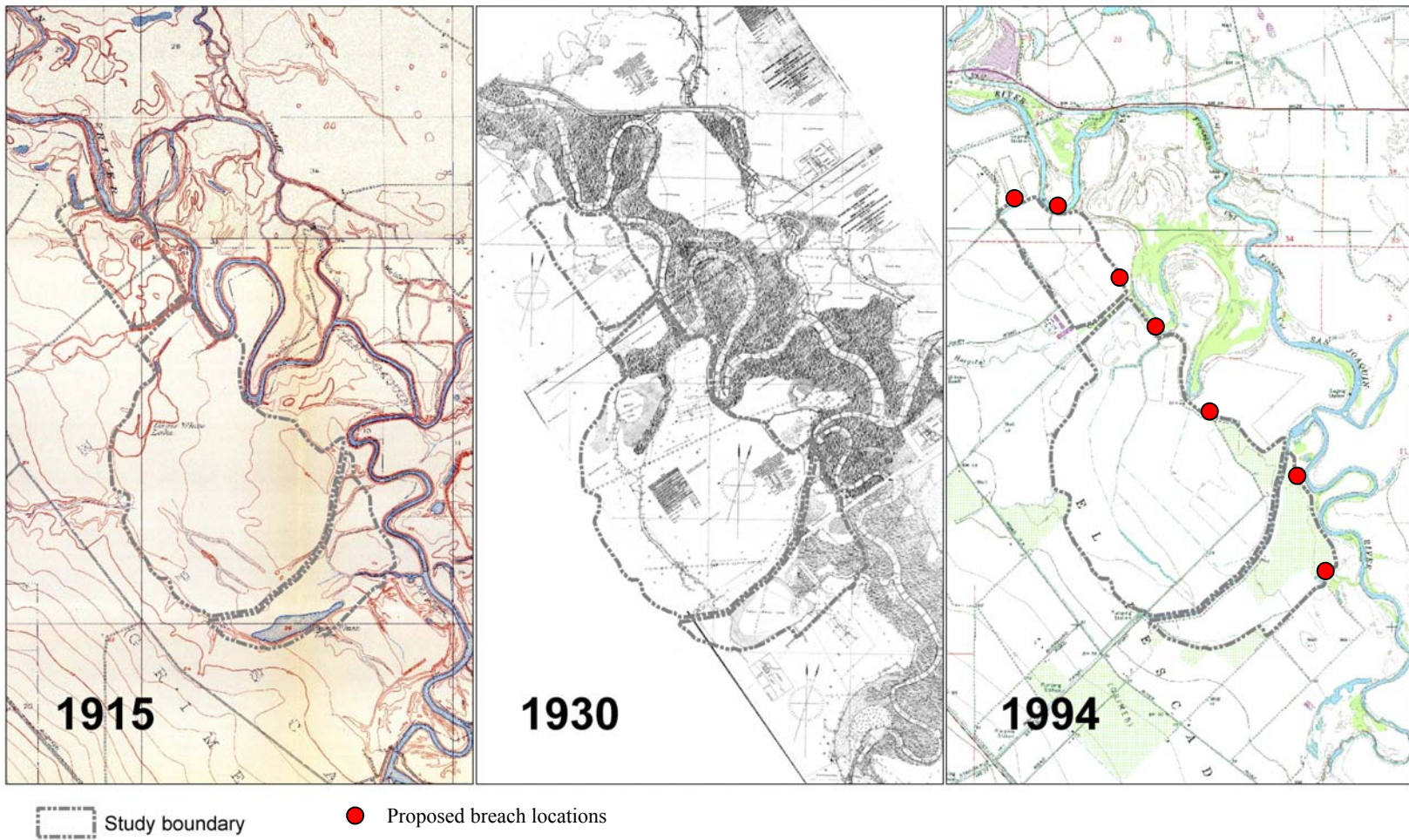
PWA

Lara

Hagemann

Approximate
location of
Lower White
Lake

Source: J. Haas, March 2004.
Notes: Lower White Lake shown drained in this photograph. View
from north to south over Refuge.

1915

1930

1994

Study boundary

Proposed breach locations

figure 3-4

San Joaquin River National Wildlife Refuge – Phase 2

Historic mapping: 1915, 1930 and 1994

PWA #: 1568

PWA

Approximate project boundary

Joins to Figure 3-6 for middle
extent of project area
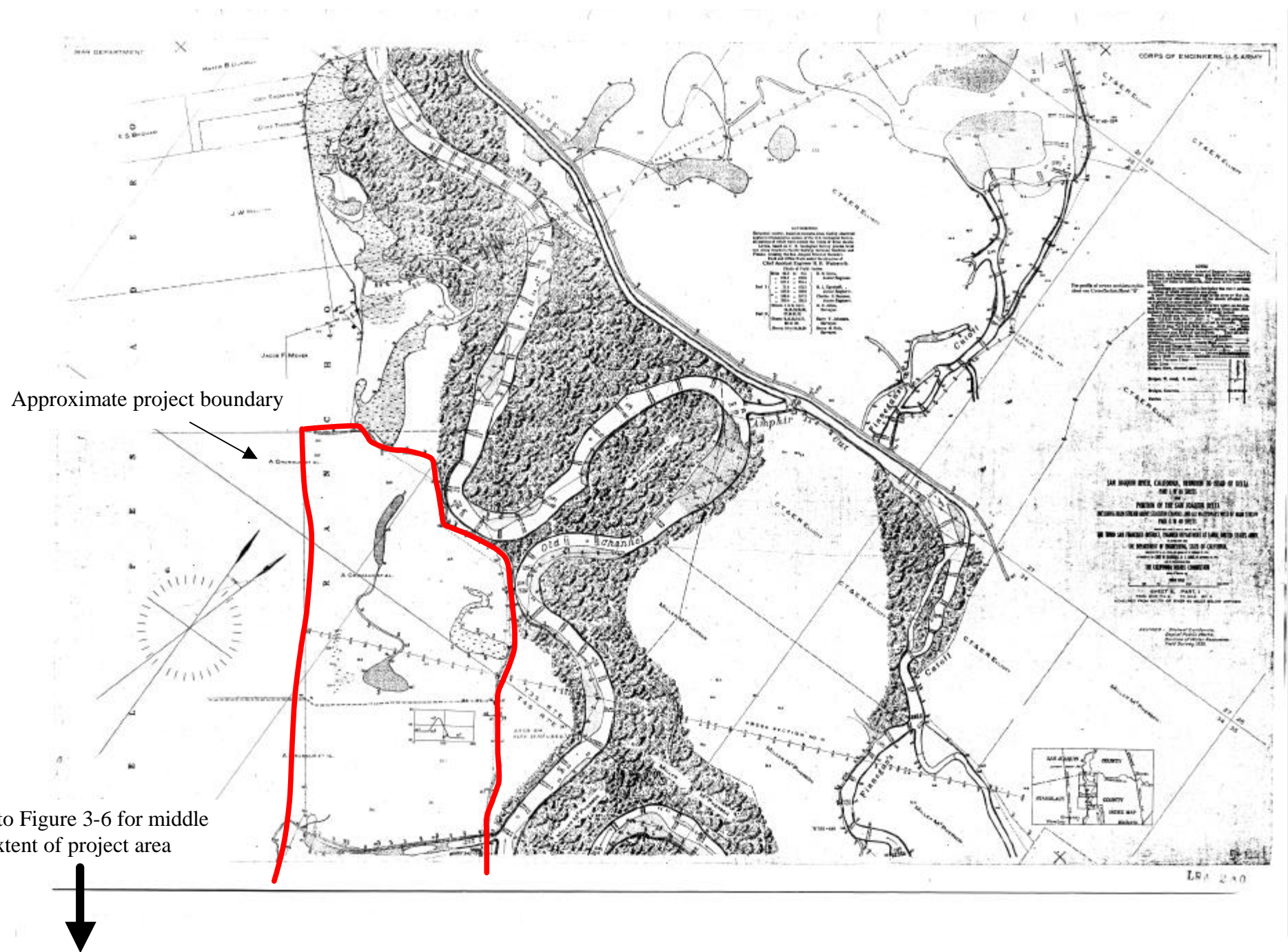
figure 3-5
San Joaquin River National Wildlife Refuge – Phase 2

1930 map – northerly extent of project area

PWA Ref# 1568

PWA

Approximate project boundary

Joins to Figure 3-7 for
southerly extent of project area
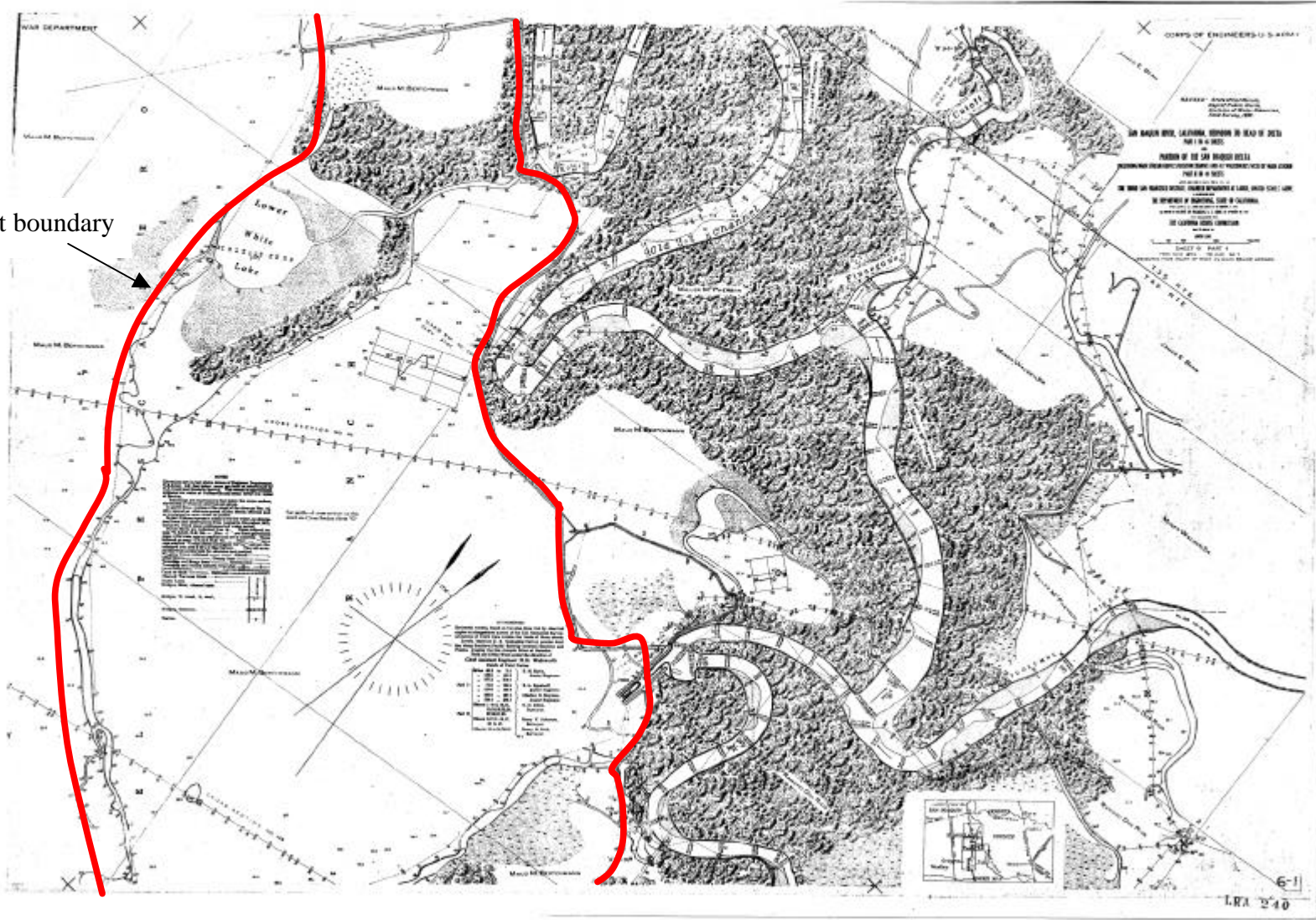
f igure 3-6
San Joaquin River National Wildlife Refuge – Phase 2

1930 map – middle extent of project area

PWA Ref# 1568

PWA

Approximate project boundary

Joins to Figure 3-6 for middle
extents of project area

f igure *3-7*
San Joaquin River National Wildlife Refuge – Phase 2

1930 map – southerly extent of project area

PWA Ref# 1568

PWA

4. DEVELOPMENT OF ALTERNATIVES

4.1   FORMULATION OF ALTERNATIVES MEETING

PWA developed preliminary proposals for two alternatives to the NSA that were presented at a meeting facilitated by PWA at the USFWS AFRP offices in Stockton on March 5, 2002. Participants at this meeting included staff from the SJRNWR, AFRP, National Oceanic and Atmospheric Administration (NOAA) Fisheries, California Department of Fish and Game (CDFG), CALFED (now California Bay Delta Authority (CBDA), USACE, (Sacramento) River Partners, the Department of Water Resources (DWR) and The Nature Conservancy (TNC). Input into potential alternatives that maximize the potential gain to native fish habitat while minimizing advantage to non-native fisheries was solicited at this meeting. During this meeting there was discussion concerning the relative merits of different breaching scenarios. Considerations included:

- The merits of breaching Hospital Creek and the West Stanislaus Irrigation Canal in relation to their impact on the site flow patterns and habitat benefits, relative to the potential risks involved.
- Pilot channels may be required to ensure effective drainage of certain areas of the SJRNWR.
- Levees would be breached to the local floodplain level.
- SJRNWR plans for the creation of managed and seasonal shallow water wetland site within the SJRNWR.
- Short-term use of irrigation ditches for promoting growth of tree plantings.
- Alternatives that consider the infilling of ditches on portions of the SJRNWR.

Anadromous fish habitat criteria were also discussed (based on the matrix established in Phase 1) in relation to the refinement and revision of alternatives. Highlighted considerations included:

- Levee breaching should be seen in the context of overall site fisheries benefits, not just benefits under flood conditions that already represent "good" conditions.
- Down-valley flows are preferable.
- Recent experience indicates that benefits accrue where topographic highpoints are added to the floodplain.
- Some hydraulically-isolated locations on the SJRNWR may be inevitable.

Three broad strategies for alternatives were agreed upon as summarized in Table 4-1.

Table 4-1 Strategies for modeling alternatives (PWA, 2002)

Alternative	USFWS Wetland Creation	Breach Configuration	West Stanislaus Canal breach	Hospital Creek breach	Pilot Channel	Micro-topography
#1: Base scenario – separate basins	Yes	Eliminate #3; enlarge/move #4	No	No	No	No
#2: Maximize down-valley flows	Yes	Eliminate #3; enlarge/move #4	Yes	Yes	No	No
#3: Detailed topographic change alternative	Yes	Eliminate #3; enlarge/move #4	No	Yes	?	Ditch infill? Others?

Following this meeting the alternatives were developed for modeling. Included in all the alternatives were the wetland creation proposed by the SJRNWR including elements that are described in greater detail in Section 5.2.1.2. Detailed topographic change in terms of micro-topography was ultimately not included in Alternative 3 due to the inability of the model to capture this micro-topography at a grid cell resolution of 45 feet (15 meters). Further details of the individual alternatives are described in the following sections.

4.1.1   Alternative 1

Lara, Hagemann and Vierra function independently as three separate floodplains with separate breaches through the project levee to the San Joaquin River(i.e., there are no breaches through the West Stanislaus canal separating Lara from Hagemann and similarly no breach at Hospital Creek separating Hagemann from Vierra.) Figure 4-1 shows the details for Alternative 1.

4.1.2   Alternative 2

Flow-through connectivity is provided between Lara, Hagemann and Vierra through breaches in the West Stanislaus Canal and Hospital Creek berms[1] and levees respectively. Figure 4-2 shows the details for Alternative 2.

---

[1] Berms here refers to non-engineered levees; in the case of the West Stanislaus Canal, these were formed by deposition of spoils from maintenance dredging.

4.1.3 Alternative 3

Connectivity is provided between Vierra and Hagemann through a levee breach across Hospital Creek. The berms on West Stanislaus Canal remain intact so that Lara continues to function independently. Figure 4-3 shows the details for Alternative 3.
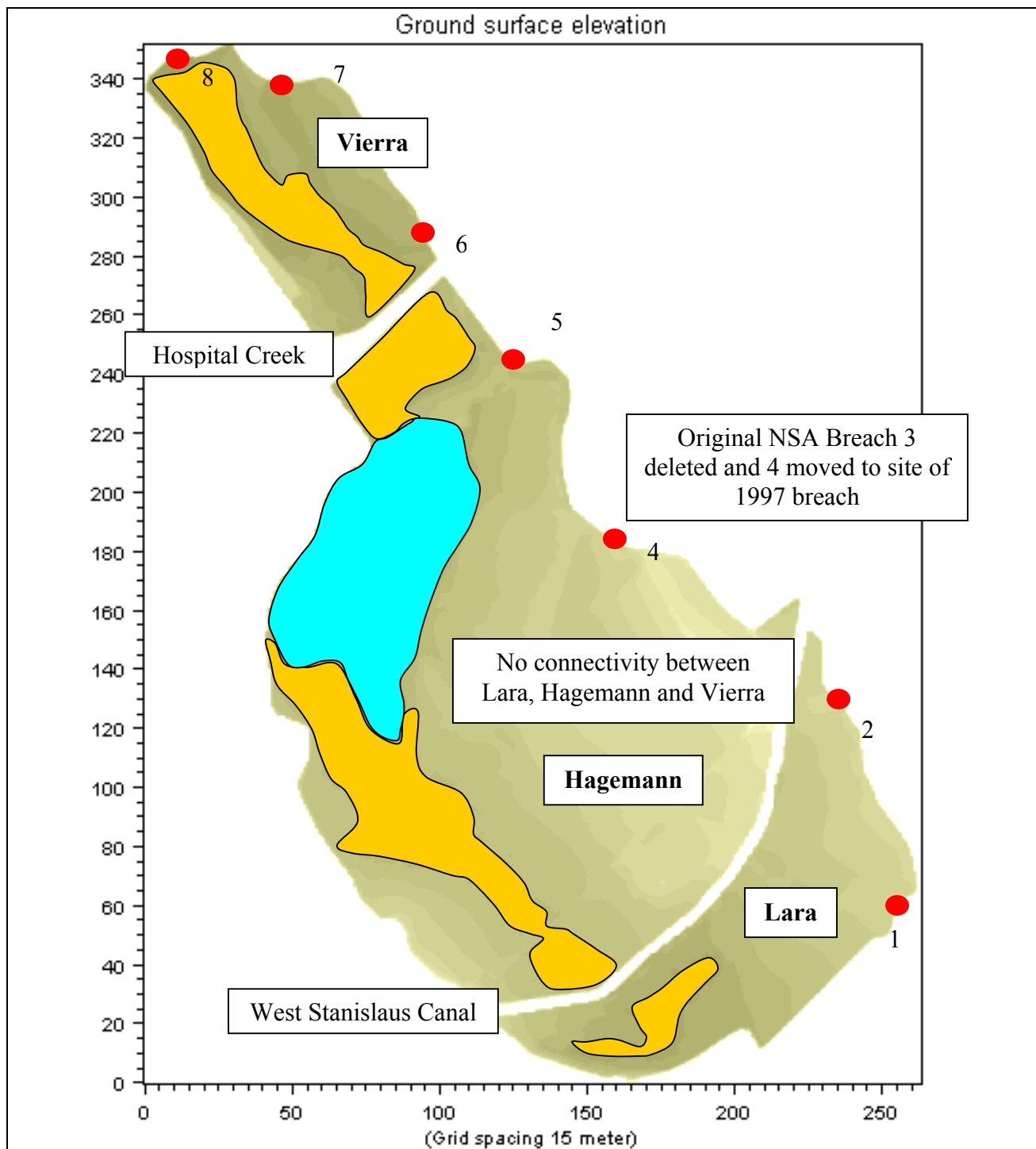
Ground surface elevation

Vierra

Hospital Creek

Original NSA Breach 3
deleted and 4 moved to site of
1997 breach

No connectivity between
Lara, Hagemann and Vierra

Hagemann

Lara

West Stanislaus Canal

(Grid spacing 15 meter)

Darker brown shades represent
lower elevations

Approximate outline of proposed
seasonal wetlands shown by

Approximate outline of proposed
seasonal wetlands shown by

PWA #: 1568

*f*igure *4-1*

San Joaquin River National Wildlife Refuge – Phase 2
Alternative 1

PWA
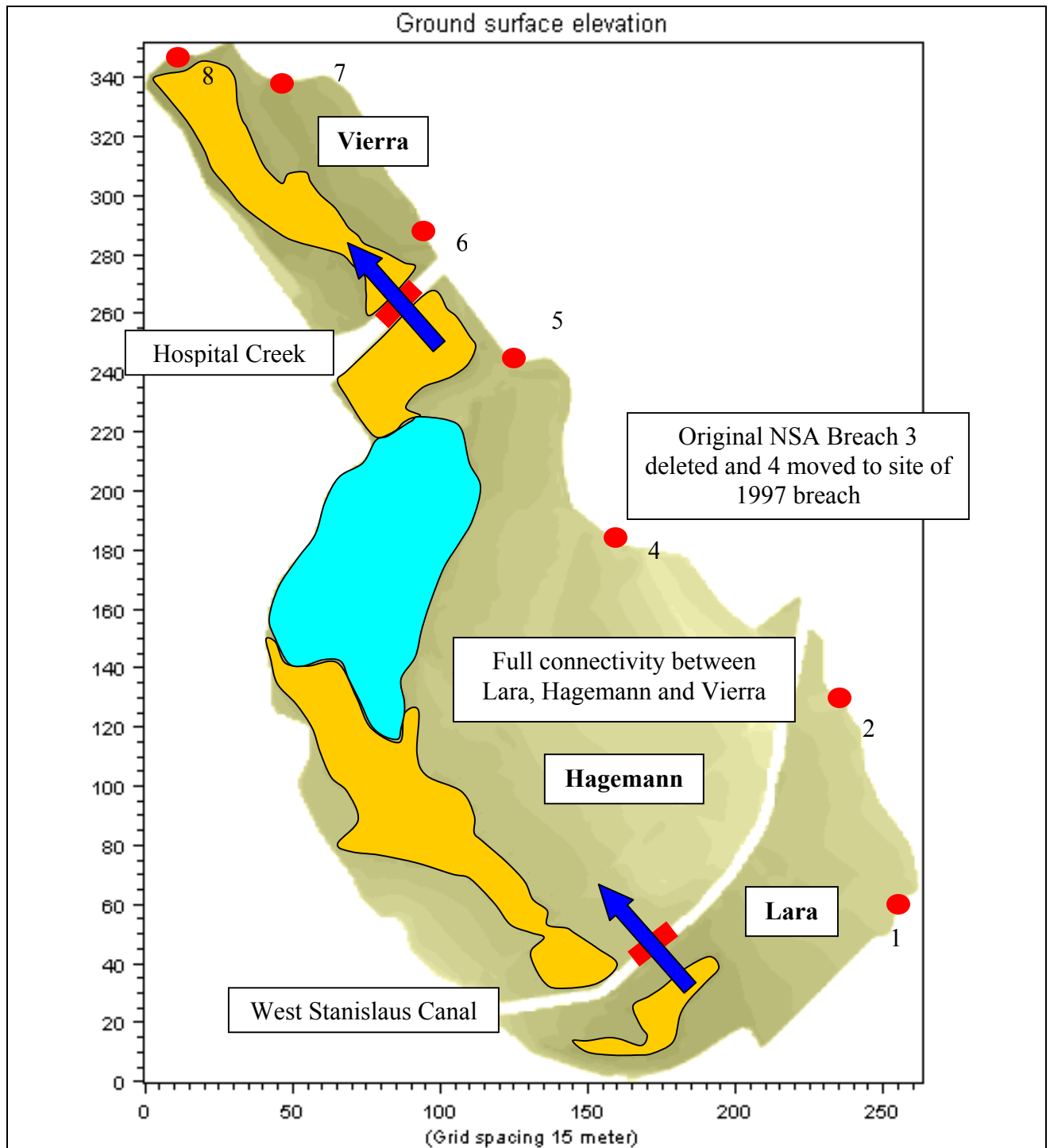
Ground surface elevation

Vierra

Hospital Creek

Original NSA Breach 3
deleted and 4 moved to site of
1997 breach

Full connectivity between
Lara, Hagemann and Vierra

Hagemann

Lara

West Stanislaus Canal

(Grid spacing 15 meter)

Darker brown shades represent
lower elevations

Approximate outline of proposed
seasonal wetlands shown by

Approximate outline of proposed
seasonal wetlands shown by

figure **4-2**

San Joaquin River National Wildlife Refuge – Phase 2
Alternative 2

PWA #: 1568

PWA
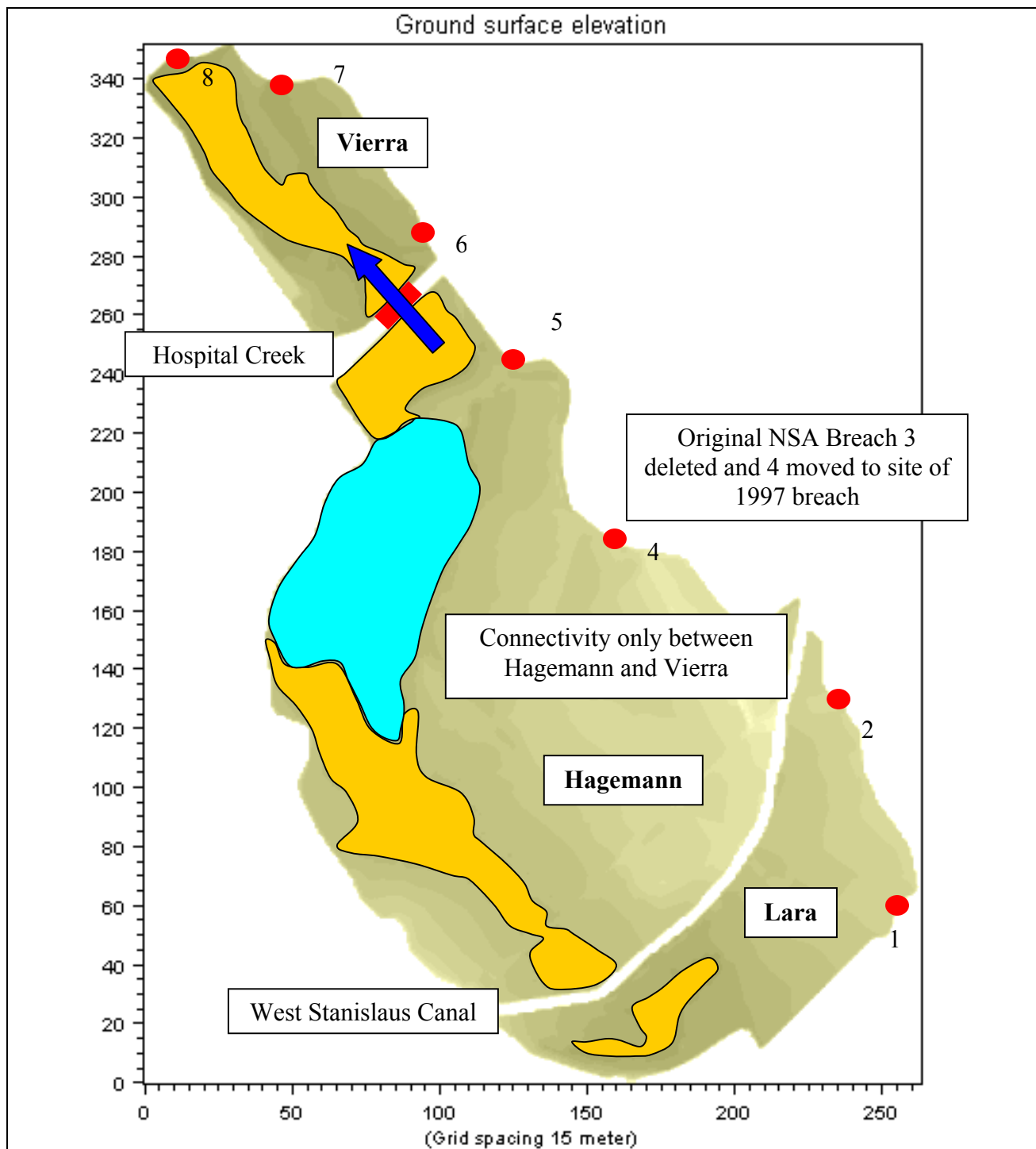
Ground surface elevation

8
7
Vierra
6
Hospital Creek
5
Original NSA Breach 3
deleted and 4 moved to site of
1997 breach
4
Connectivity only between
Hagemann and Vierra
2
Hagemann
Lara
1
West Stanislaus Canal

(Grid spacing 15 meter)

Darker brown shades represent
lower elevations

Approximate outline of proposed
seasonal wetlands shown by

Approximate outline of proposed
seasonal wetlands shown by

figure 4-3

San Joaquin River National Wildlife Refuge – Phase 2
Alternative 3

PWA #: 1568

PWA

5. METHODOLOGY

5.1   INTRODUCTION

PWA developed a one-dimensional/two-dimensional (1D/2D) coupled hydrodynamic model to compare habitat benefits of three proposed levee breaching alternatives. The 1D portion of the model includes the area outside of the SJRNWR study area (Venn, Hagemann and Lara properties). A 2D grid-based model was applied to the SJRNWR itself. The models were coupled through levee breaches modeled as broad-crested weirs, approximately 100 feet wide. The proposed breaches through the berms on Hospital Creek and the West Stanislaus Canal were modeled as 200-foot wide breaches.

5.2   HYDRODYNAMIC MODEL REFINEMENTS

Various model refinements were made from the original 1D model used for Phase 1 of the study, as described below.

5.2.1   Creation of Digital Terrain Model

A substantial component of the model refinements for Phase 2 of the project included creating a digital terrain model (DTM) to be used for construction of the 2D element of the hydraulic model. Phase 1 findings included a recommendation to improve the topographic description of the SJRNWR portion of the model. Previous modeling in Phase 1 used topography for the SJRNWR floodplain based on a USGS 30-meter Digital Elevation Model (DEM). The creation of the DTM for the current study incorporated additional topographical surveys by DU and modification for the proposed wetlands design by the SJRNWR.

5.2.1.1   Topographical Surveys

PWA coordinated with DU to undertake the topographic surveying on the floodplain of the SJRNWR. The surveying was undertaken by DU using a combination of survey methods, including conventional total station surveys and surveys using all-terrain-vehicles connected to GPS technology. These survey methods were used to cover the floodplains of the Lara, Hagemann and Vierra basins with a grid of levels spaced approximately 100 to 300 feet apart. Various drainage and irrigation ditches on the floodplain were surveyed using a series of cross–sections and profiles were surveyed along the tops of all major levees.

The resulting topographic plot showing spot elevations and contours is shown by Figure 5-1.
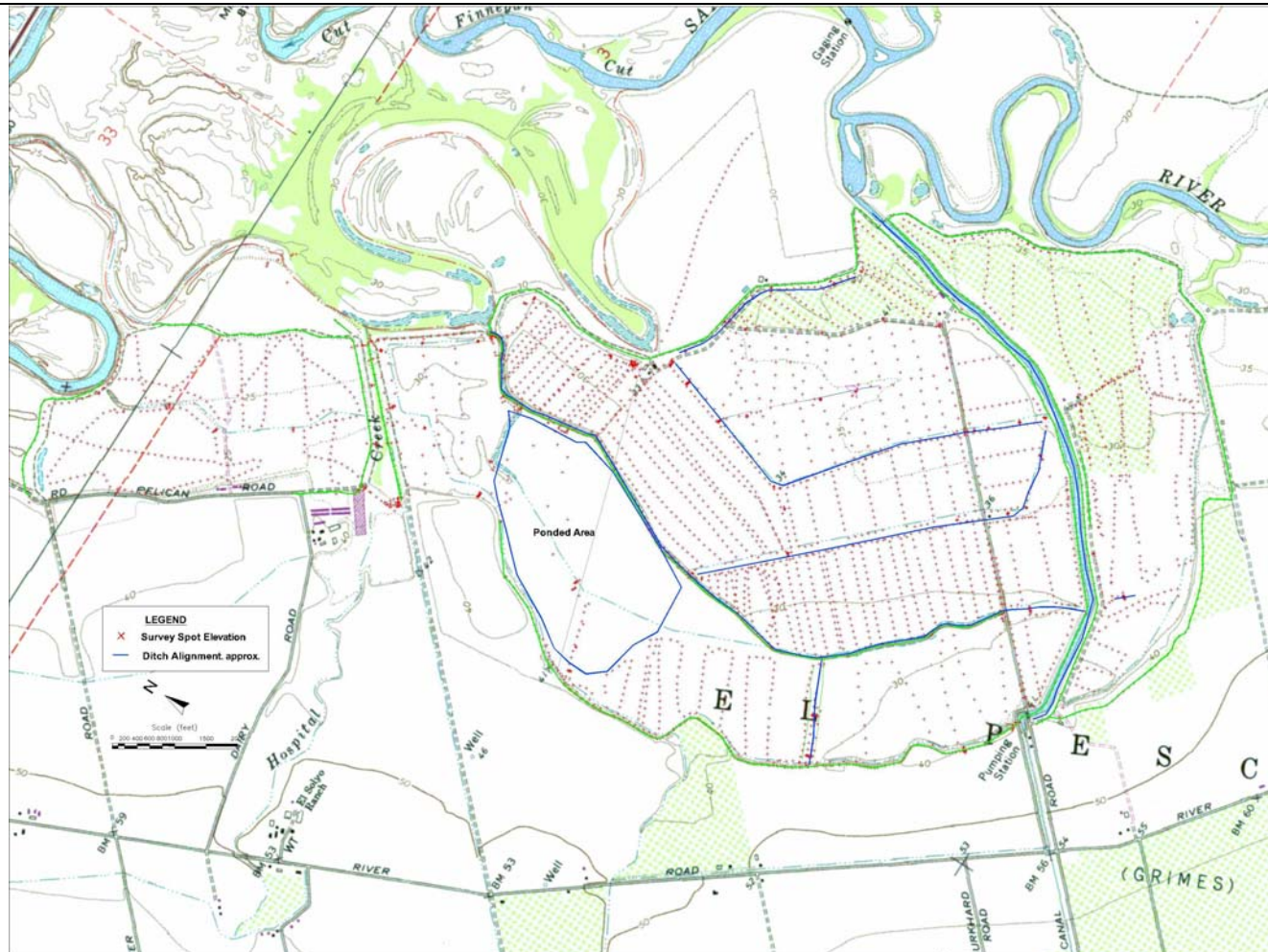
5.2.1.2   USFWS Wetland Design (Base Condition)

PWA coordinated with the SJRNWR staff to incorporate the proposed seasonal and managed wetland designs into the surface model (DTM) to be used in the 2D model. PWA produced a conceptual design drawing based on the design input of the SJRNWR staff. The conceptual design drawing is shown in Figure 5-2.

The conceptual design for the seasonal and managed wetlands was incorporated into all three alternatives. The proposed conceptual design consists of areas of managed wetlands, areas of seasonal wetlands and manipulations to the existing drainage infrastructure by filling in of ditches. The key features of the design are summarized as follows:

Lower White Lake:
- Manage water level to 27.5 ft (summer), 28.5 ft (winter), NGVD.
- Protect drainage along existing ditch.
- Remove spoil banks where indicated in Figure 5-2.
- Install 36" water control structure at outlet.

White Lake:
- Manage water level to 28.5 ft, NGVD.
- Protect existing berm to separate lake from main ditch.
- Install 36" water control structure with screen gate.
- Replace pipe crossing with siphon.
- Install ditch block and 36" water control structure between Seasonal Basin A and White lake.
- Remove spoil banks where indicated in Figure 5-2.

Upper White Lake:
- Manage water level to 26.0 ft, NGVD.
- Remove spoil banks where indicated in Figure 5-2.
- Install outlet structure to intake canal.

Seasonal Basin A:
- Manage water level to 30.0 ft, NGVD.
- Install berm between White Lake and Seasonal Basin A.
- Remove spoil banks where indicated in Figure 5-2.

Seasonal Basin B:
- Manage water level to 25.5 ft, NGVD.
- Remove spoil banks where indicated in Figure 5-2.
- Install low flow channel.

The SJRNWR also has a legal drainage obligation to agricultural concerns upslope of the SJRNWR. These were taken into account in the conceptual design of the SJRNWR's wetland enhancement project. The legal obligation to provide drainage to upslope lands complements the need to provide positive drainage to minimize fish stranding, including the capacity to completely drain wetlands.

Further details of the wetlands conceptual design are shown in Appendix A.

Notes: A large scale plot is included as an attachment to this report

f igure *5-2*
San Joaquin River National Wildlife Refuge – Phase 2

Seasonal wetland conceptual design drawing

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5.2.2   Extension of Downstream Model Boundary

The downstream model boundary was extended from Maze Road Bridge to Vernalis according to a Phase 1 recommendation that the model boundary be sufficiently removed from the area of interest. The extended portion of the model was constructed with USACE Comp Study topography for the San Joaquin River from Maze Road Bridge to the USGS San Joaquin River near Vernalis (11303500) stream gage. The rating curve at the Vernalis gage was used as a downstream boundary for the model. Vernalis is downstream of the confluence with the Stanisluas River, so a model boundary was added at this location to represent Stanislaus River inflows to the system. Sensitivity tests show that Stanislaus River inflows do not significantly influence water levels in the project reach.

5.2.3   Transition to a 1D/2D Coupled Model

Phase 1 recommendations included refining the Phase 1 1D hydrodynamic model through improving the accuracy and detail of the topographic characterization of the SJRNWR. Following this recommendation, a Phase 2 1D hydrodynamic model of the SJRNWR was constructed based on the December 2001/February 2002 DU survey of the SJRNWR, which was later found to be flawed. At the time the flaws were identified by USFWS and a resurvey of portions of the SJRNWR was imminent, the completed Phase 2 1D model had already undergone QAQC by DHI, Inc. Flood mapping in MIKE11 GIS was also underway.

The decision to move from a 1D model to a 1D/2D coupled model was made to simplify the reconstruction of the model from new survey data, while improving model detail. The process of extracting or "cutting" cross-sections and alignments from a surface model or digital terrain model (DTM) for input to a 1D model can prove time-consuming in such a complex model. In addition, an accurate understanding of flow patterns must be understood for construction of 1D model branches and linkages. In contrast, 2D model topography is based almost directly on the surface model itself, eliminating several potentially time intensive steps in the model construction process.

Thus, a 1D/2D coupled MIKEFLOOD model was selected, whereby only the SJRNWR bounded by the project limits is modeled in 2D. The remainder of the model (extents described elsewhere) is modeled in 1D and coupled to the SJRNWR through the proposed levee breaches (represented as 1D channels with broad-crested weirs). The 1D and 2D models run simultaneously/interactively, exchanging flow and water level data at the coupled boundaries.

Initially the SJRNWR was modeled with a 5-meter grid that described all of the interior irrigation ditches and berms, and was coupled to the exterior 1D model through breaches (weirs) and culverts. Though the culverts were found to be the largest source of instabilities in the model, ultimately the 5-meter grid was abandoned for a larger grid cell size, because model instabilities occurred even at a 2-second time step. At 2 seconds, simulation of the design storm through the peak also required an excessive run time, exceeding one week.

Ultimately, a 15-meter grid was selected, which does not have sufficient resolution to explicitly include the SJRNWR irrigation ditches and berms. The model has the advantage of running at a 5 second timestep, and taking a total of 24 hours of run time for the simulated event (25 days). Interior ditches and drainage structures are not necessary for the purposes of the current study, which is to differentiate the hydraulic characteristics, as related to habitat value, of the three alternatives. The simulations assume the drainage of the floodplain to a certain point on the receding limb of the hydrograph. It was not computationally efficient to simulate full drainage of the floodplain but the simulation results do indicate the rate at which alternatives drain.

5.2.4 Verification of 1D Uncoupled Model at Maze Road

The 1D portion of the model was run independently or "uncoupled" for the historic period of December 4, 1996 – March, 4, 1997. Modeled water levels and discharge were compared with observed water levels and discharge at Maze Road Bridge for that period. Roughness values were raised from 0.033 to 0.045 in the river channels, raising the maximum-modeled water level at Maze Road from 37.4 feet to 39.4 feet to match the measured water level of 39.4 feet. Modeled and observed water surface elevations for the 1D model are plotted in Figure 5-3.

The current 1D model is not considered a "calibrated" model, because only a single calibration point was available. However, the model performance is accurate for purposes of this study, and the use of the Maze Road observations to improve roughness values improves the estimation of inundation frequencies at the project site.

5.2.5 QA/QC of Hydrodynamic Model

DHI, the developers of the modeling software used in this study, provided QA/QC for the original Phase 2, 1D model. PWA revised the model according to the recommendations of DHI. The resulting model formed the foundation for the final 1D/2D coupled model that was ultimately used in this study. Many of the recommendations by DHI pertained to areas outside of the SJRNWR (Phase 1 model), which form the 1D portion of the coupled model. Thus, the final 1D/2D coupled model benefited from the QA/QC by DHI.

The 2D portion of the model underwent qualitative and quantitative QA/QC by PWA staff. The lead modeler performed standard stability and QA/QC tests throughout model development. Other PWA technical and management level staff provided input and review of model setup, parameters, and results at various stages of model development.

San Joaquin River at Maze Road
MIKE11 Calibration - Water Surface Elevation

Legend:
- Observed
- Phase I Roughness: 0.033 Manning's Roughness on Mainstem
- 0.045 Mainstem Roughness
- 0.05 Mainstem Roughness

Y-axis: Elevation, m NGVD

X-axis: Time
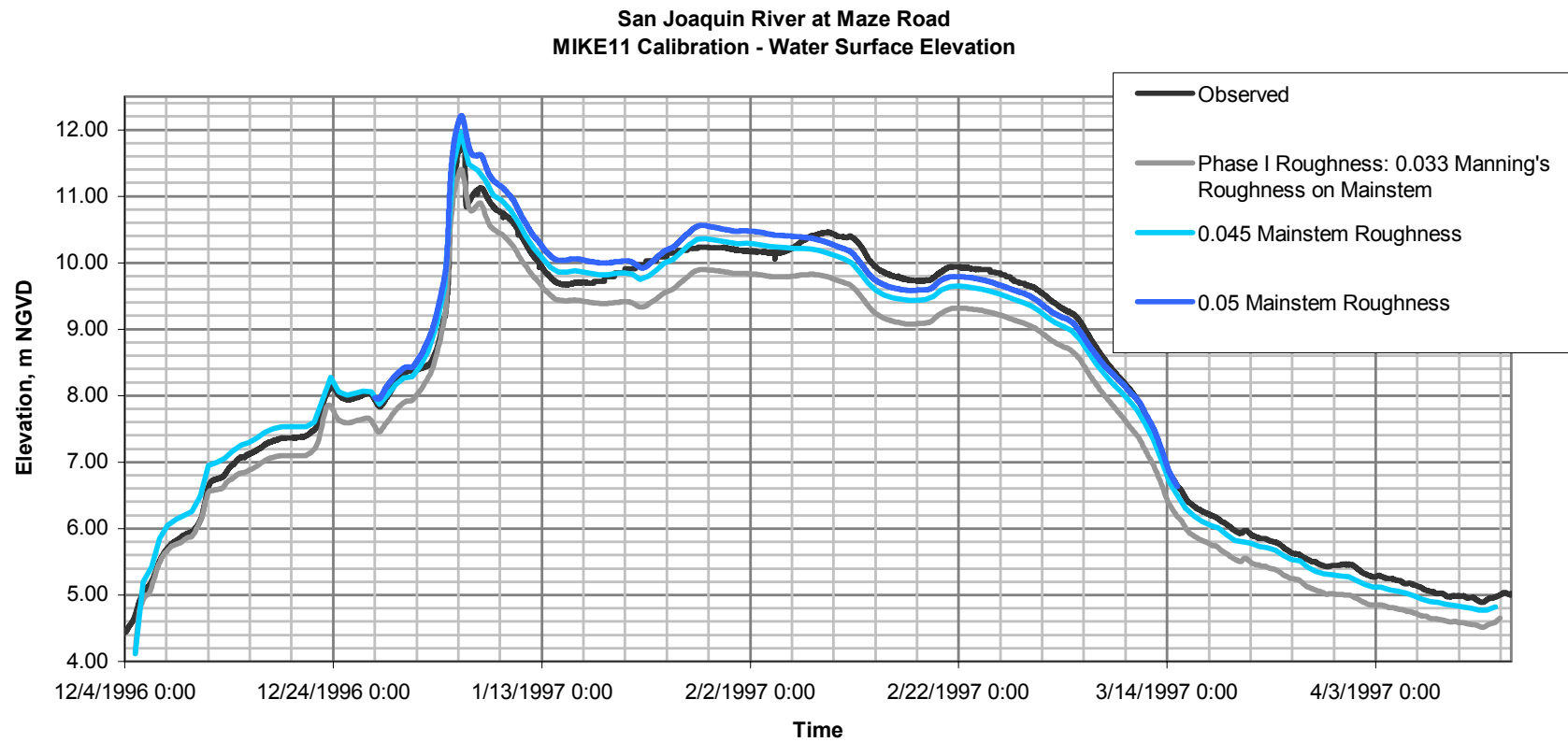
figure **5-3**

San Joaquin River National Wildlife Refuge – Phase 2

Modeled and observed water surface elevations for the 1D calibration

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5.3   SELECTION OF HYDROGRAPH

Phase 1 model results indicate that the SJRNWR will just begin to flood in a 2-year recurrence interval flood event. This is the minimum recurrence interval identified in the Habitat Evaluation Criteria as benefiting Sacramento splittail. A larger, approximately 10-year recurrence interval, event was selected for Phase 2 modeling to therefore include a range of flows that would be potentially beneficial to anadromous and resident fish and significantly inundate the floodplain to clearly show the hydraulic differences between the three alternatives.

The USACE published flood frequency curves for stream gages USGS San Joaquin River near Newman (11274000), USGS Tuolumne River at Modesto (11290000) and DWR San Joaquin River near Maze Road Bridge (MRB) (USACE, 2000). San Joaquin River near Newman and Tuolumne River at Modesto are model boundaries; San Joaquin River near Maze Road Bridge is an intermediate point in the model, just downstream of the study site. The historic flow records at these gages were inspected for an historic event that closely approximates a 10-year peak flow event at all three gages. Ultimately, the historic storm of July 1995, which has a recurrence interval of approximately 5-years at Newman and Maze Road stream gages, was scaled up to a 10-year peak flow magnitude. The resulting synthetic hydrograph has a peak flow recurrence interval of 10 years in the project reach (upstream of the Tuolumne), as shown in Table 5-1.

For the July 1995 storm, Stanislaus inflows were negligible. Through sensitivity testing, modeled water surfaces in the project reach were found to be insensitive to Stanislaus River inflows. In addition, Hospital Creek and West Stanislaus Canal inflows were not modeled because they are an insignificant source of flow during large events compared to the San Joaquin River, and because the flows are not relevant to the comparison of breaching scenarios being undertaken in the current analysis.

Applying the Phase 1 model, upstream inflows from Tuolumne River at Modesto and San Joaquin River near Newman were translated (with constant time lags) downstream, so that the model domain could be reduced. Design storm inflow hydrographs for San Joaquin River and Tuolumne River are shown in Figure 5-4. Table 5-1 shows the equivalent recurrence interval of the synthetic hydrograph used in the simulation.

Table 5-1 Modeled synthetic storm, based on July 1995 hydrograph

Gauge	Synthetic Hydrograph Peak Discharge (cfs)	Peak Recurrence Interval[1] (years)
San Joaquin River near Newman	21,025	10
Tuolumne River at Modesto	14,807	40
San Joaquin River near Maze Rd Bridge	34,008	17

[1]Regulated conditions flood frequency analysis (USACE, 2000)

SJRNWR, Design Inflows for the San Joaquin and Tuolumne River
~10-Year Recurrence Interval Storms
Note: Design hydrographs derived from USGS gage records at Newman and Modesto factored with a ratio of USACE FFA 10-year to 5-year peaks
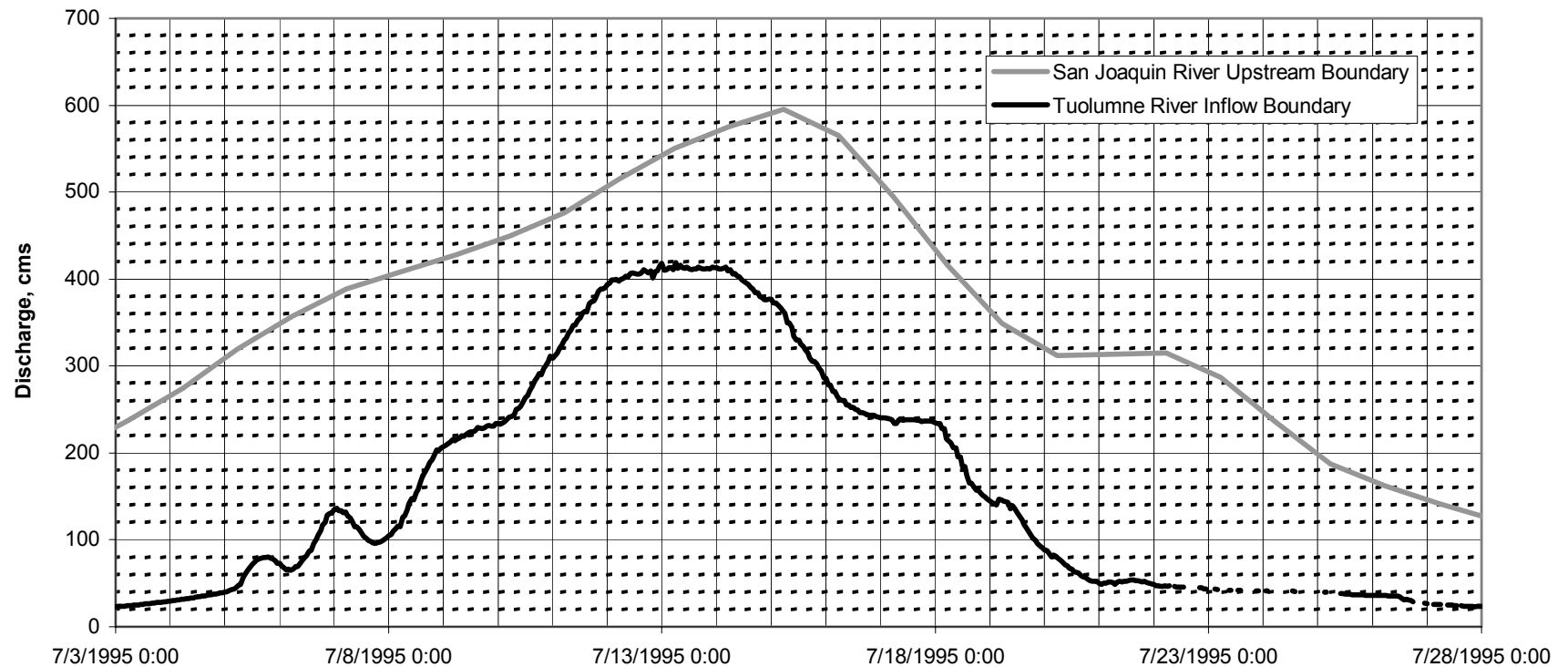
figure **5-4**

San Joaquin River National Wildlife Refuge – Phase 2
July 1995 hydrographs of San Joaquin River and Tuolumne River

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6. EVALUATION OF MODEL RESULTS

The evaluation of model results is presented in terms of six parameters: frequency of flooding, area and duration of inundation, flow patterns, flooding depth and velocity on the floodplain. Inundation timing is not discussed here as timing is driven by the particular San Joaquin River flow regime and does not vary between Alternatives. For locations and identifiers of breaches and basin names see Figure 6-1.

6.1   FREQUENCY OF FLOODING

Table 6-1 shows the water level, flow, exceedence probability and the corresponding recurrence interval (in years) for flows in the San Joaquin River for the approximate point at which each of the basins (Lara, Hagemann and Vierra) in the SJRNWR start to spill through the proposed breaches for each of the alternatives.

Table 6-1 Exceedence frequency – start of flooding on SJRNWR

	Alternative 1			
	Water level (ft)[1]	**Flow (cfs)[1]**	**Annual Exceedence Probability[2]**	**Recurrence Interval (yr)[2]**
Lara	21.9	8,581	49%	2.0
Vierra	24.5	11,089	42%	2.4
Hagemann	25.9	13,773	37%	2.7

	Alternative 2			
	Water level (ft)[1]	**Flow (cfs)[1]**	**Annual Exceedence Probability[2]**	**Recurrence Interval (yr)[2]**
Lara	21.9	8,546	49%	2.0
Vierra	24.2	11,336	41%	2.4
Hagemann	23.8	10,877	43%	2.3

	Alternative 3			
	Water level (ft)[1]	**Flow (cfs)[1]**	**Annual Exceedence Probability[2]**	**Recurrence Interval (yr)[2]**
Lara	21.9	8,581	49%	2.0
Vierra	24.2	11,407	41%	2.4
Hagemann	24.6	11,760	40%	2.5

[1] Modeled water level and flow at maze Road are reported; modeled flow differs from 1997 and 1999 DWR rating curve at same water level by 6-11%.

[2] Estimated annual exceedence frequency at Maze Road Bridge from Phase I frequency analysis (PWA, 2001).

This table shows that the various basins within the floodplain start to inundate (or have a threshold flow) between a 2.0 - and 2.7-year event for flows in the San Joaquin River depending on the alternative. It should be noted that this range of inundation frequencies is different from the inundation frequency predicted by the model used in Phase 1 of the study. The 1D model used in Phase 1 of the study predicted

an average inundation frequency at which flows (approximately 16,000 cfs) start to spill onto the project site floodplain of 3.3 years. The likely reasons for this difference are:

- The increased level of detail included in the Phase 2, 1D/2D model which accounts more accurately for variations in floodplain topography.
- Extending the boundary of the model downstream of the Maze Road Bridge.
- Adjusting Mannings 'n' for the San Joaquin River based on the model refinements and partial calibration.

General observations about the data shown in Table 6-1 include the following:

1. Lara inundates first at the lowest flow of 8,546 cfs in the San Joaquin River (2.0-year recurrence interval) in Alternative 2. The inundation flow rate for Lara of 8,581 cfs occurs in Alternative 1 and 3.
2. Vierra inundates next after Lara in Alternative 1 (11,089 cfs) and Alternative 3 (11,407 cfs) whereas Hagemann inundates next after Lara in Alternative 2 (10,877 cfs).
3. In Alternatives 1 and 3 Hagemann inundates last out of the three basins (13,773 cfs and 11,760 cfs for Alternative 1 and 3 respectively).

In order to calculate the summary statistics for years since 1980 in which the threshold flow was exceeded, it was necessary to assess a median flow rate from Table 6-1. This median flow rate was assessed to be approximately 11,000 cfs and the results are shown in Table 6-2. Figure 6-2 shows graphically the data shown in Table 6-2.

Table 6-2 Summary statistics for years since 1980 in which threshold flow (11,000 cfs) was exceeded

Water Year	Total days Q > 11,000 cfs	Days/Event Q > 11,000 cfs	Time Period
1981 - 1982	55	55	April 2 - May 26
1982 - 1983	232	232	December 3 - July 22
1983 - 1984	86	27	October 6 - November 2
		59	December 5 - February 2
1985 - 1986	62	13	February 21 - March 5
		49	March 10 - April 27
1994 - 1995	111	101	March 13 - June 21
		10	July 10 - July 19
1995 - 1996	32	32	February 21 - March 23
1996 - 1997	83	83	December 20 - March 12
1997 - 1998	165	165	February 4 - July 18
1998 - 1999	5	4	February 14 – 17
		1	February 23
1999 - 2000	19	1	February 25
		18	February 29 – March 17

Figure 6-2 and Table 6-2 differ from the similar figure and table shown in the Phase 1 report (Figure 9, page 20 and Table 3, page 25 respectively). The differences are due to a lower threshold flow of 11,000 cfs that was re-calculated in Phase 2. The lower threshold flow of 11,000 cfs will result in not only more frequent inundation (2.0 to 2.7-year recurrence interval) but also longer duration of inundation. For example, the Phase 1 model predicted that in water year 1997 to 1998 there would be 104 days when the flow in the San Joaquin would exceed 16,000 cfs, as opposed to this study, in which the revised model predicted that there would be inundation of the floodplain for up to 165 days when the flow exceeded 11,000 cfs.
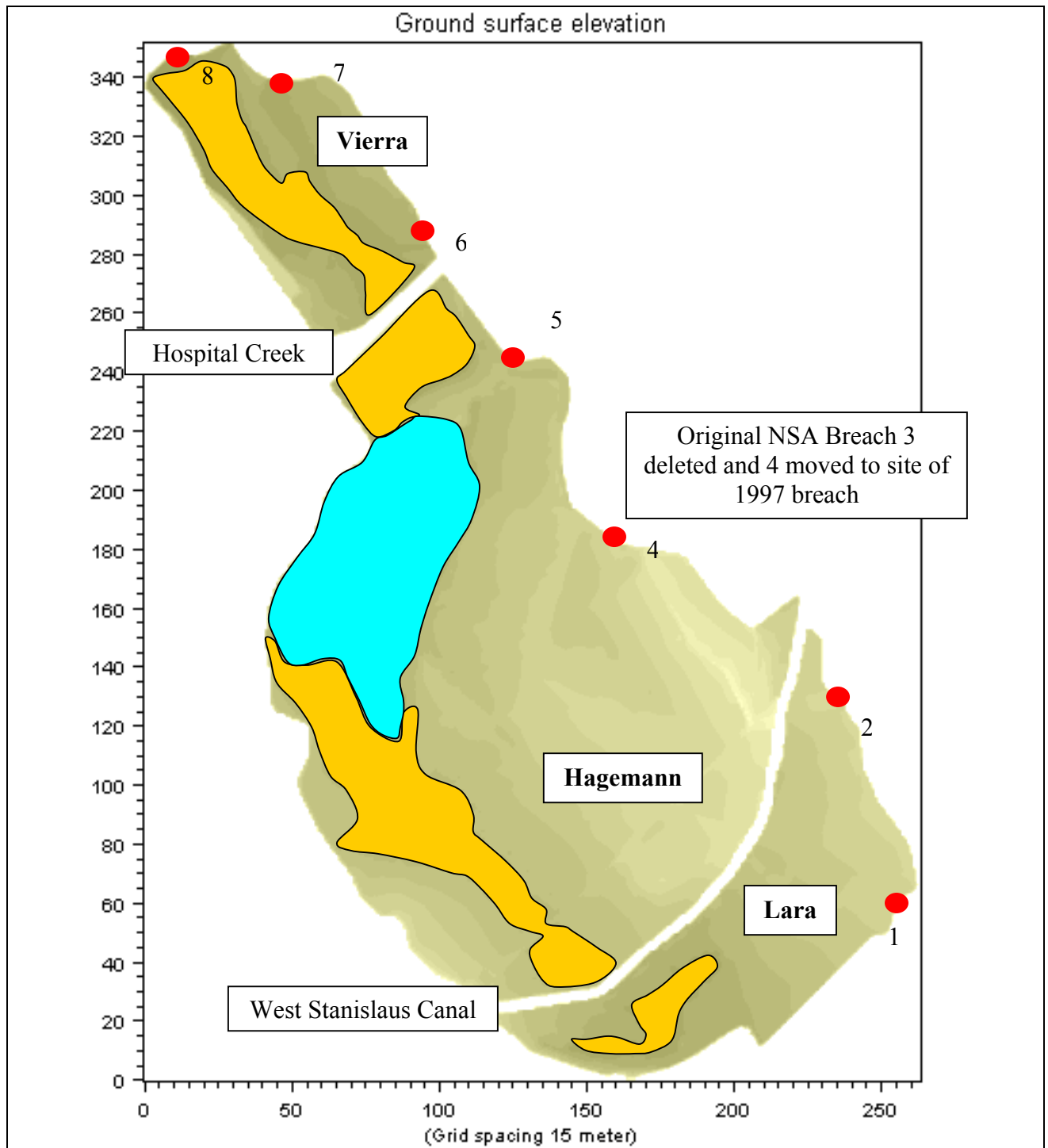
Ground surface elevation

Vierra

7

8

6

Hospital Creek

5

Original NSA Breach 3
deleted and 4 moved to site of
1997 breach

4

2

Hagemann

Lara

1

West Stanislaus Canal

(Grid spacing 15 meter)

Darker brown shades represent lower elevations

Approximate outline of proposed seasonal wetlands shown by

Approximate outline of proposed seasonal wetlands shown by

figure 6-1

San Joaquin River National Wildlife Refuge – Phase 2
Breach locations and basin names

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Number of Days in Particular Year Flow Exceeded Threshold
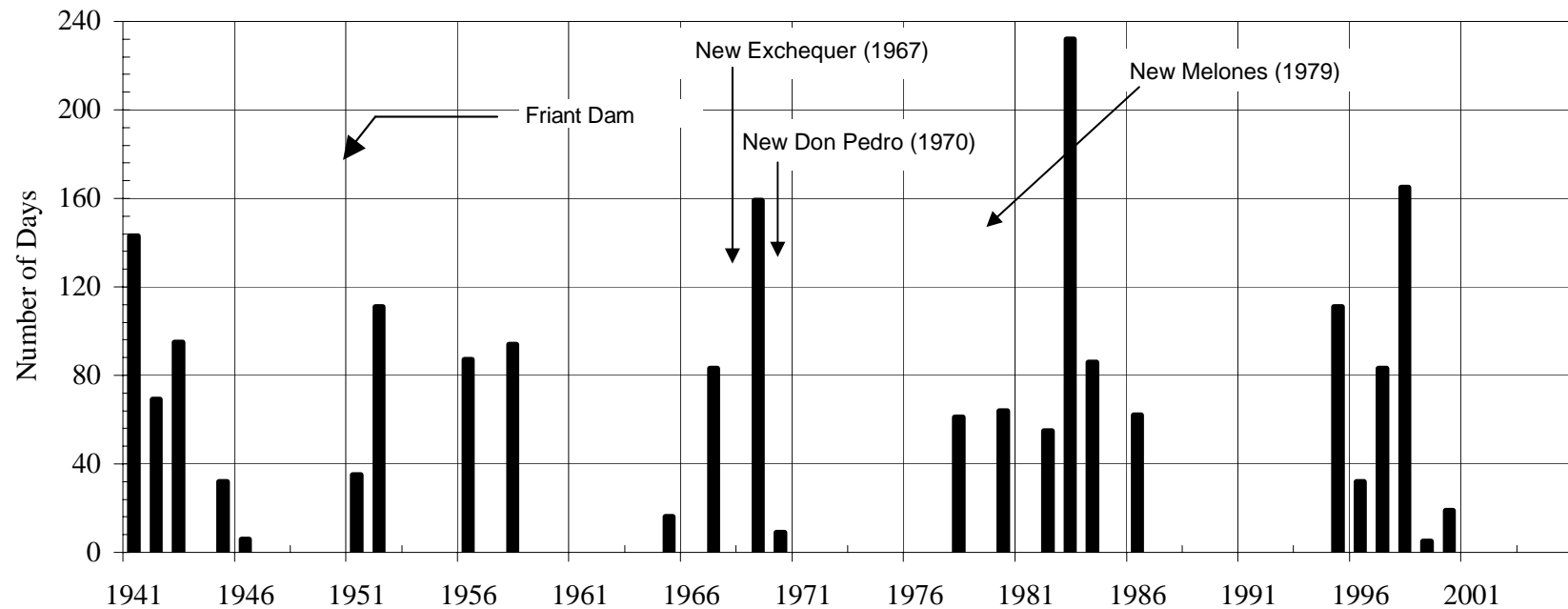
Source: USGS San Joaquin R Nr Vernalis Ca (11303500)
         USGS Stanislaus R at Ripon (11303000)
Period of Record: 1940-2004

figure 6-2

San Joaquin River National Wildlife Refuge – Phase 2
Flows over threshold of 11,000 cfs

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6.2   AREA AND DURATION OF INUNDATION

The area and duration of floodplain inundation in a given flood will be affected by floodplain drainage facilities. However, for the purposes of modeling inundation of the floodplains of the SJRNWR specific drainage structures were not included into the computational domain of the hydraulic model. In terms of modeling, this network of drainage structures it was not practical to represent them in the model due to the grid cell resolution of the model domain in which the grid cells were 15 meters square (approximately 45 feet). However, since the capacity of drainage structures is negligible in comparison to the capacity of the floodplain, it was considered that not including them in the model would have a negligible effect on the area of inundation. Similarly in terms of drainage, the rate of drainage is not significantly affected by the lack or representation of the drainage network in the model.

Presently the field staff of the SJRNWR are able to regulate the area and depth of inundation on the seasonal wetlands. The field staff have the most control of Lower White Lake which they are able to completely drain, if so required, using an existing lift pump near to the location of the proposed Breach 5 (see Figure 6-1). There are also several culvert structures and ditches that traverse the project site. Using this network of drainage structures the field staff has the ability to transfer drainage from the surrounding farmland which passes into the SJRNWR into the San Joaquin River.

Table 6-3 shows the area and volume of ponding following the recession of the flood hydrograph in the San Joaquin River. This table is useful to highlight the drainage characteristics of each alternative. It should not be used to directly indicate areas of fish stranding due to ponding. The simulations undertaken for this study did not extend for the full drainage period of the receding limb of the flood hydrograph.

Figure 6-3 shows total area-duration curves for the three alternatives. In addition, planimetric plots of inundation at three instances for each alternative are shown by Figure 6-4 to Figure 6-6. These figures show the inundation during initial flooding, near to the peak of the flooding and towards the end of inundation during draining. The figures show these respective time periods for each of the alternatives to enable comparison to be made. The results shown by Figure 6-3 to Figure 6-6 can be summarized as follows:

1. Alternative 1 inundates to the largest maximum acreage of approximately 1,830 acres.
2. Alternatives 2 and 3 inundate to approximately the same maximum acreage of approximately 1,820 acres.
3. Alternative 2 inundates the most rapidly of all three alternatives, followed by Alternative 3, with Alternative 1 inundating the least rapidly.
4. Alternative 1 drains the least rapidly of all three alternatives, with Alternative 2 draining slightly more rapidly than Alternative 3.

Table 6-3 Area and volume of ponding following flood recession

Floodplain	Total floodplain area (acres)	Alternative 1		
		Ponded area (acres)	% of total area	Volume of ponding (ac-ft)
Vierra	293	200	68%	302
Hagemann	1,505	757	50%	1,911
Lara	400	344	86%	1,321
Total	2,198	1,301	59%	3,535

Floodplain	Total floodplain area (acres)	Alternative 2		
		Ponded area (acre)	% of total area	Volume of ponding (ac-ft)
Vierra	293	201	68%	303
Hagemann	1,505	420	28%	813
Lara	400	170	43%	335
Total	1,905	791	22%	1,451

Floodplain	Total floodplain area (acres)	Alternative 3		
		Ponded area (acre)	% of total area	Volume of ponding (ac-ft)
Vierra	293	206	70%	331
Hagemann	1,505	499	33%	885
Lara	400	344	86%	1,310
Total	1,905	1,050	72%	2,526

Figure 6-4 to Figure 6-6 show planimetric plots of inundation at selected time periods for each alternative. (For users of an electronic version of this report, animations of the inundation of each alternative are provided in Section 6.6).
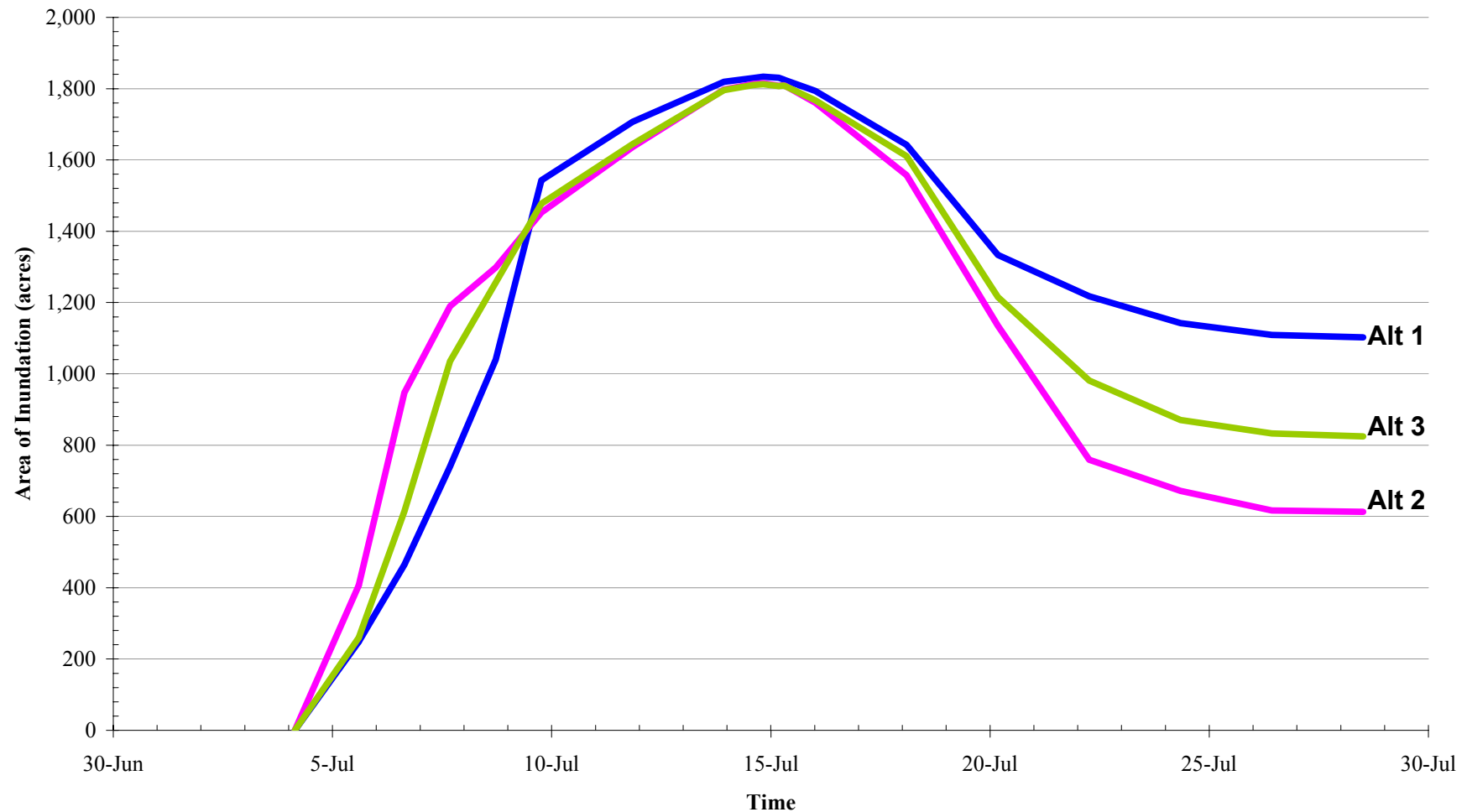
Total area-duration curves for flood depths between 6 inches and 6 feet

Flood

Peak

Pond

07/07/95 16:20:00

07/14/95 19:50:00

07/28/95 12:20:00
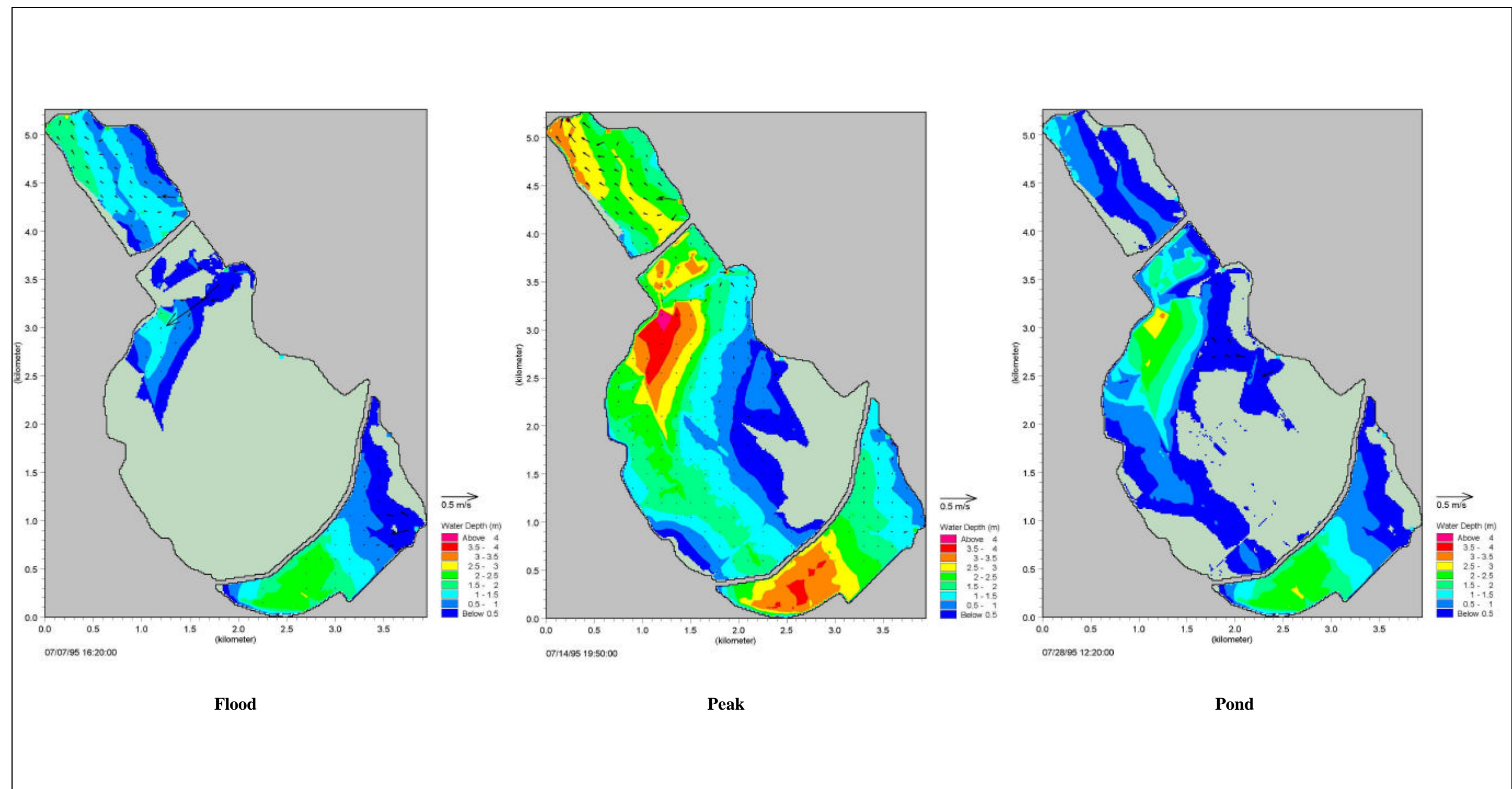
Notes:

f igure 6-4
San Joaquin River National Wildlife Refuge – Phase 2

Planimetric plots of inundation for Alternative 1

PWA Ref# 1568

PWA

Flood

07/07/95 16:20:00

Peak

07/14/95 19:50:00

Pond

07/28/95 12:20:00

Water Depth (m)
Above 4
3.5 - 4
3 - 3.5
2.5 - 3
2 - 2.5
1.5 - 2
1 - 1.5
0.5 - 1
Below 0.5

0.5 m/s
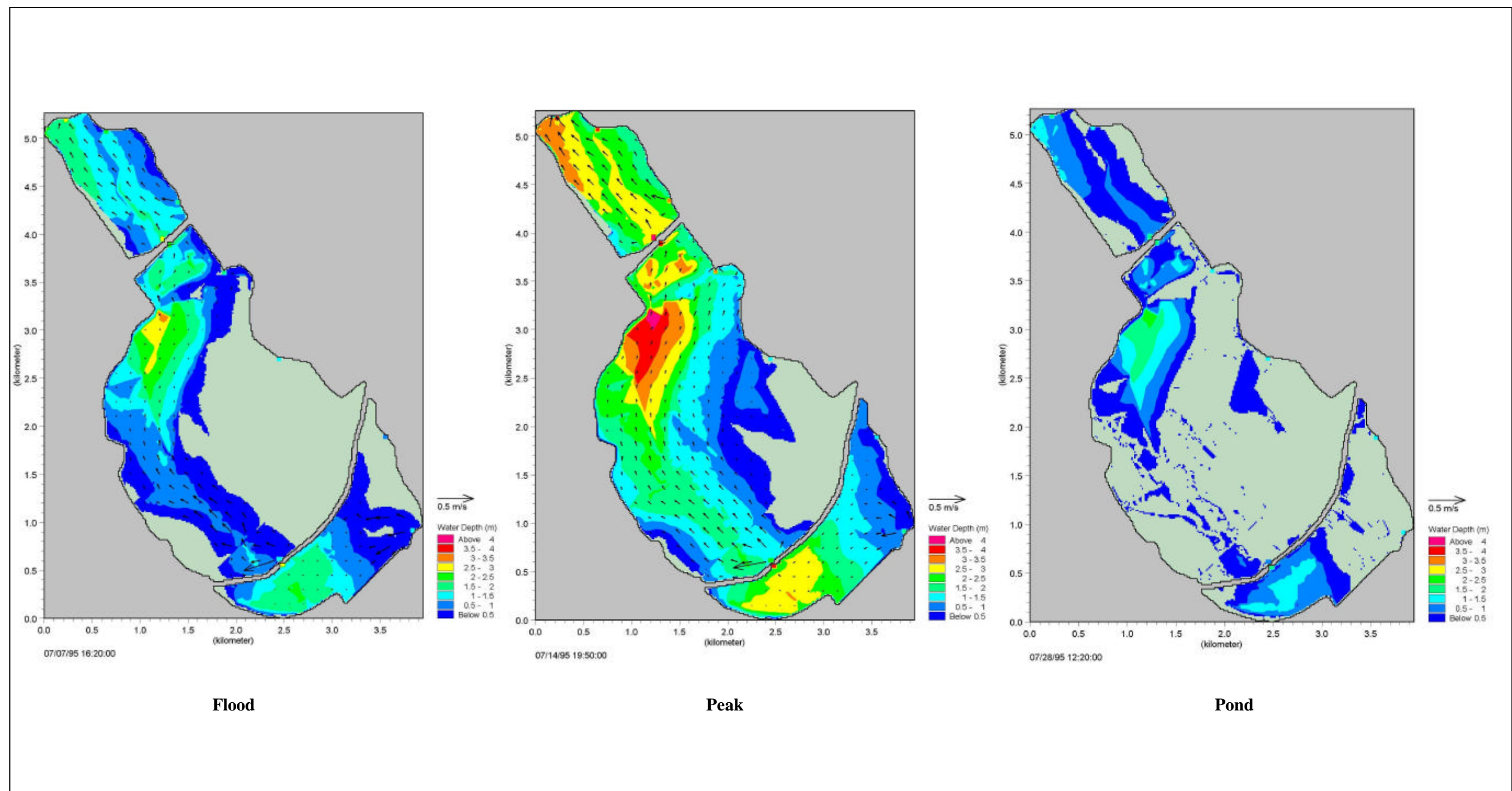
Notes:

f igure 6-5
San Joaquin River National Wildlife Refuge – Phase 2

Planimetric plots of inundation for Alternative 2

PWA Ref# 1568

PWA

Flood   **Peak**   **Pond**

07/07/95 16:20:00   07/14/95 19:50:00   07/28/95 12:20:00

Notes:

f igure 6-6
San Joaquin River National Wildlife Refuge – Phase 2

Planimetric plots of inundation for Alternative 3

PWA Ref# 1568

PWA
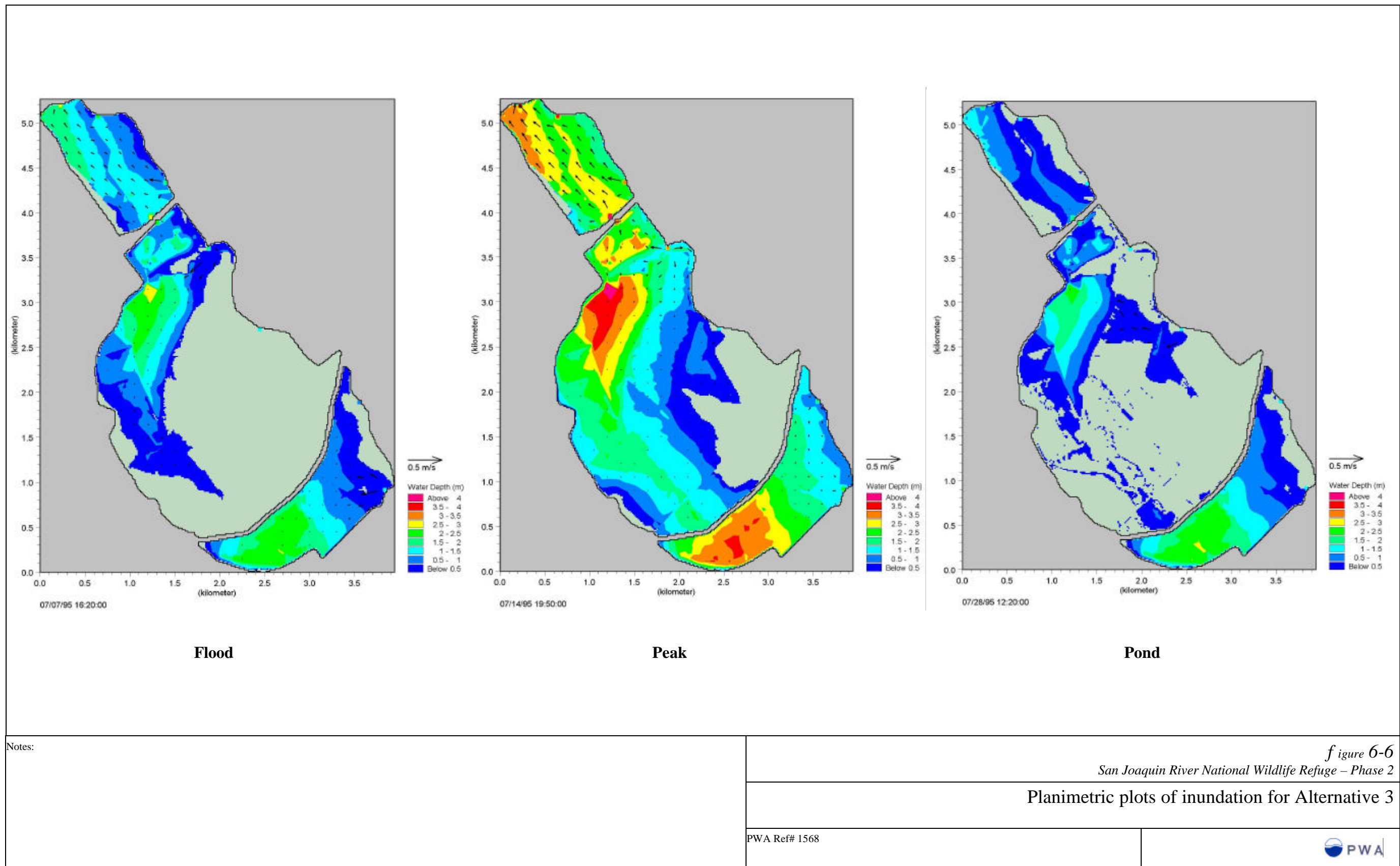
6.3   FLOW PATTERNS

The results shown by Figure 6-7 to Figure 6-12 and are summarized by property (Vierra, Hagemann and Lara) in the following sections.

6.3.1   Flows through Breaches on Vierra

1. Breach 8 (Vierra north) conveys the largest proportion of flows out of the floodplain for all three alternatives. This is intuitively reasonable, since topographically this breach is at the lowest elevation of the floodplain. Breach 8 conveys between approximately 89,500 acre-feet (Alternative 1) to 102,500 acre-feet (Alternative 2) out of the floodplain.
2. Breach 8 conveys a maximum flow of approximately 5,650 ft^3/s (Alternative 1) out of the floodplain. For Alternative 2 and 3 the maximum flow out of the floodplain through Breach 8 is approximately 4950 ft^3/s.
3. In Alternative 1, Breaches 6 and 7 (Vierra) function similarly, conveying comparable flows into Vierra, with Breach 6 conveying slightly more volume (52,000 acre-feet) than Breach 7 (44,500 acre-feet).
4. In Alternative 2, Breach 6 conveys significantly greater flows than Breach 7 (flows through breach 7 are negligible), with the connection to Hospital Creek having a significant flow through effect from Hagemann. Therefore, it appears that flows passing into Vierra as a result of connection to Hospital Creek override inflows from Breach 7.
5. Similarly for Alternative 3, Breach 6 and the connection to Hospital Creek supply most of the flows to Vierra, with most of the flow draining out of Vierra through Breach 8.

6.3.2   Flows through Breaches on Hagemann

1. Breach 4 is the least effective of all the breaches on the floodplain at this size of flood event since it conveys negligible flows for all three alternatives.
2. In Alternative 1, the greatest proportion of the floodplain flows enter and exit Hagemann through Breach 5.
3. In Alternative 2, significant flows enter Hagemann through the West Stanislaus Canal (up to 3,500 ft^3/s). This has a major effect on flows into Hagemann. Similar volumes enter Hagemann through Breach 5 as Alternative 1, but Breach 5 drains a significantly greater proportion of the flows in Alternative 2 (8,000 acre-feet) than in Alternative 1 (800 acre-feet). Also, most of the flows out of Hagemann pass through Hospital Creek into Vierra in Alternative 2.
4. In Alternative 3, Breach 5 is significantly more effective in conveying flows into Hagemann than in Alternatives 1 or 2. No flows drain out of Breach 5 in Alternative 3. Flows pass directly out of Hagemann through the Hospital Creek connection into Vierra.

6.3.3   Flows through Breaches on Lara

1. Generally Lara has smaller flow volumes/rates passing through it than Hagemann or Vierra for all three alternatives, and it floods at lower flows.
2. In all three alternatives, Breach 1 conveys flows into Lara.
3. In Alternative 1 and 3, Lara functions as an independent system with Breach 1 conveying flows into the floodplain and Breach 2 conveying flows out of the floodplain.
4. In Alternative 2, Breach 2 is largely ineffective (relatively minor flows are conveyed into or out of Lara through this breach). Larger flow volumes are generally conveyed into Lara through Breach 1 and out of Lara through the West Stanislaus Canal (up to 17,000 acre-feet).
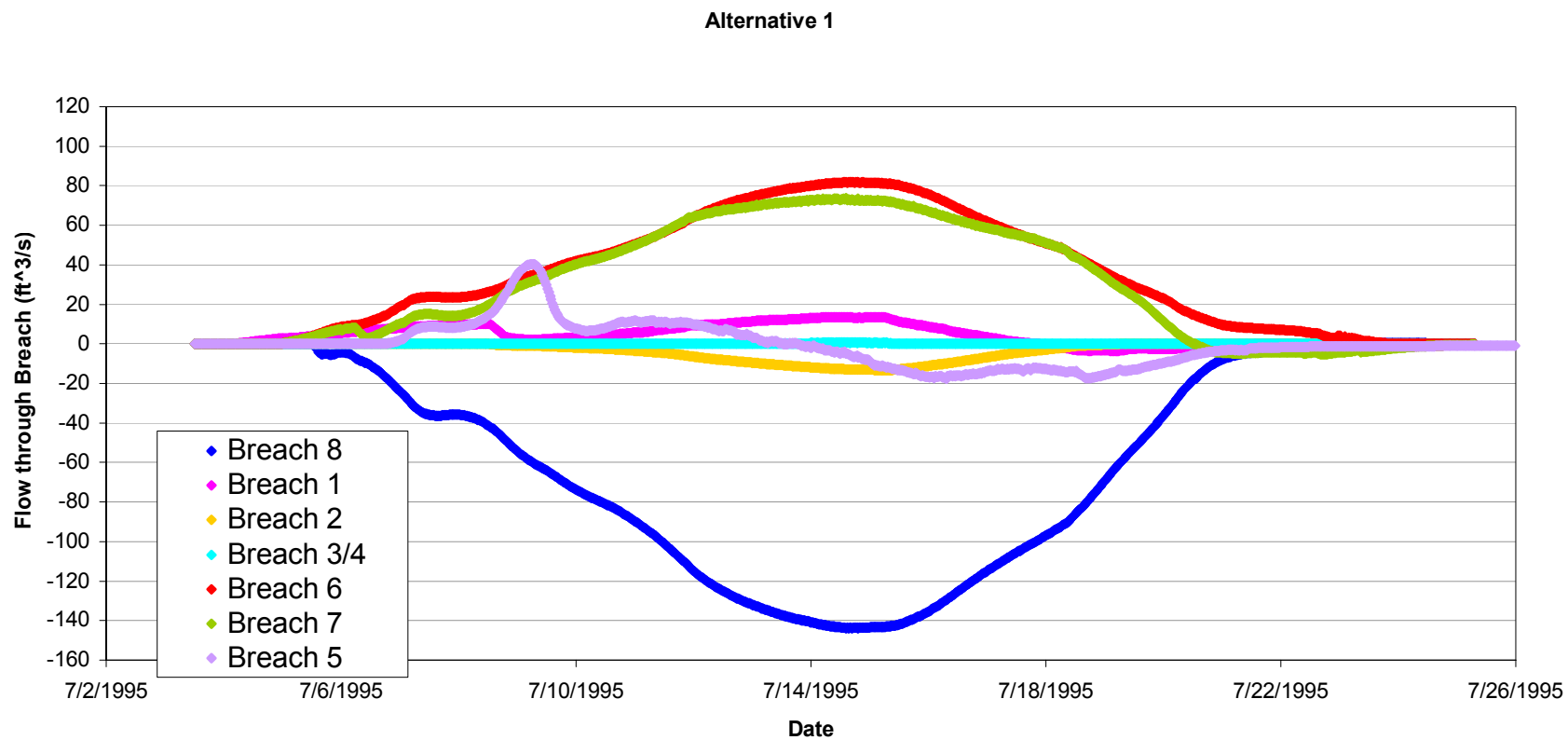
Alternative 1

figure *6-7*

San Joaquin River National Wildlife Refuge – Phase 2

Flows through breaches – Alternative 1

PWA #: 1568

PWA
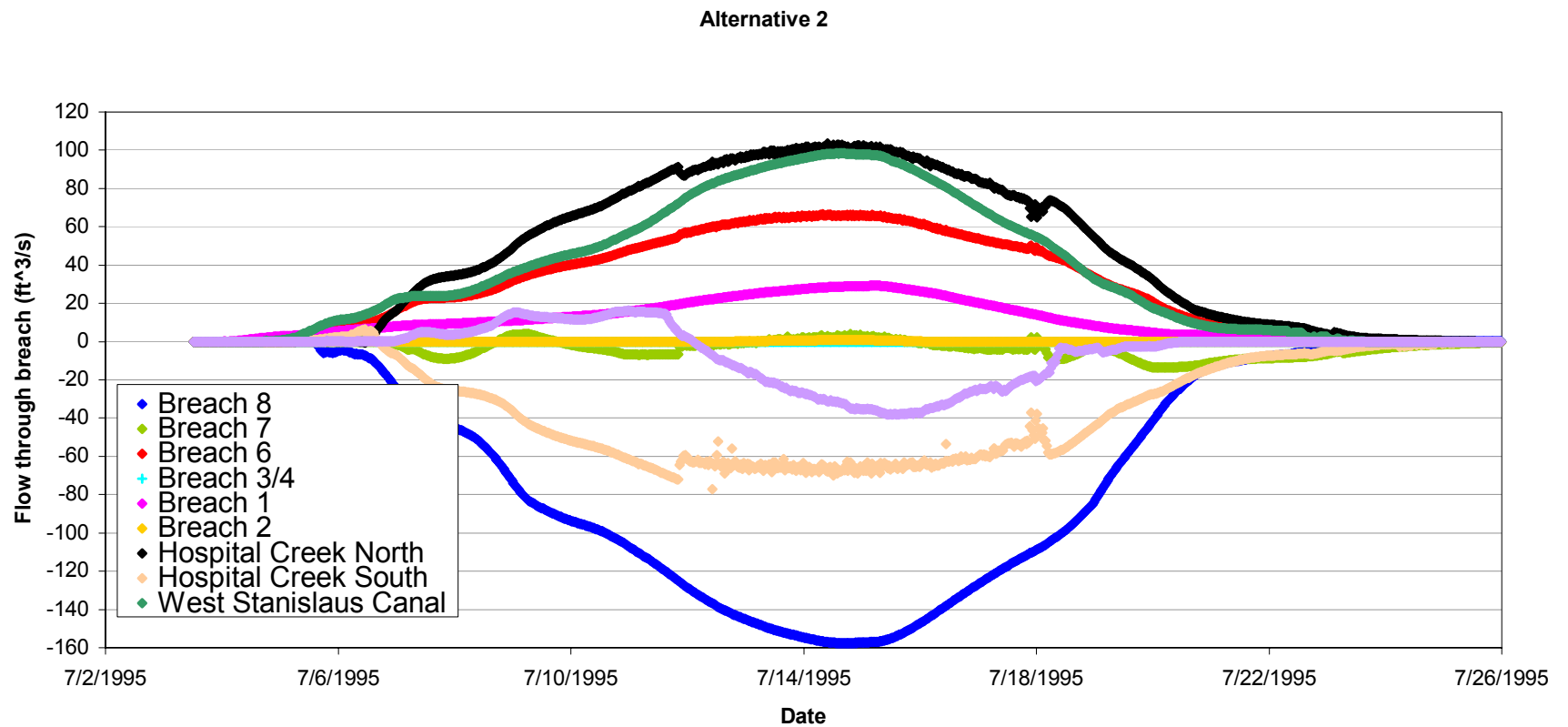
Alternative 2

figure 6-8

San Joaquin River National Wildlife Refuge – Phase 2

Flows through breaches – Alternative 2

PWA #: 1568
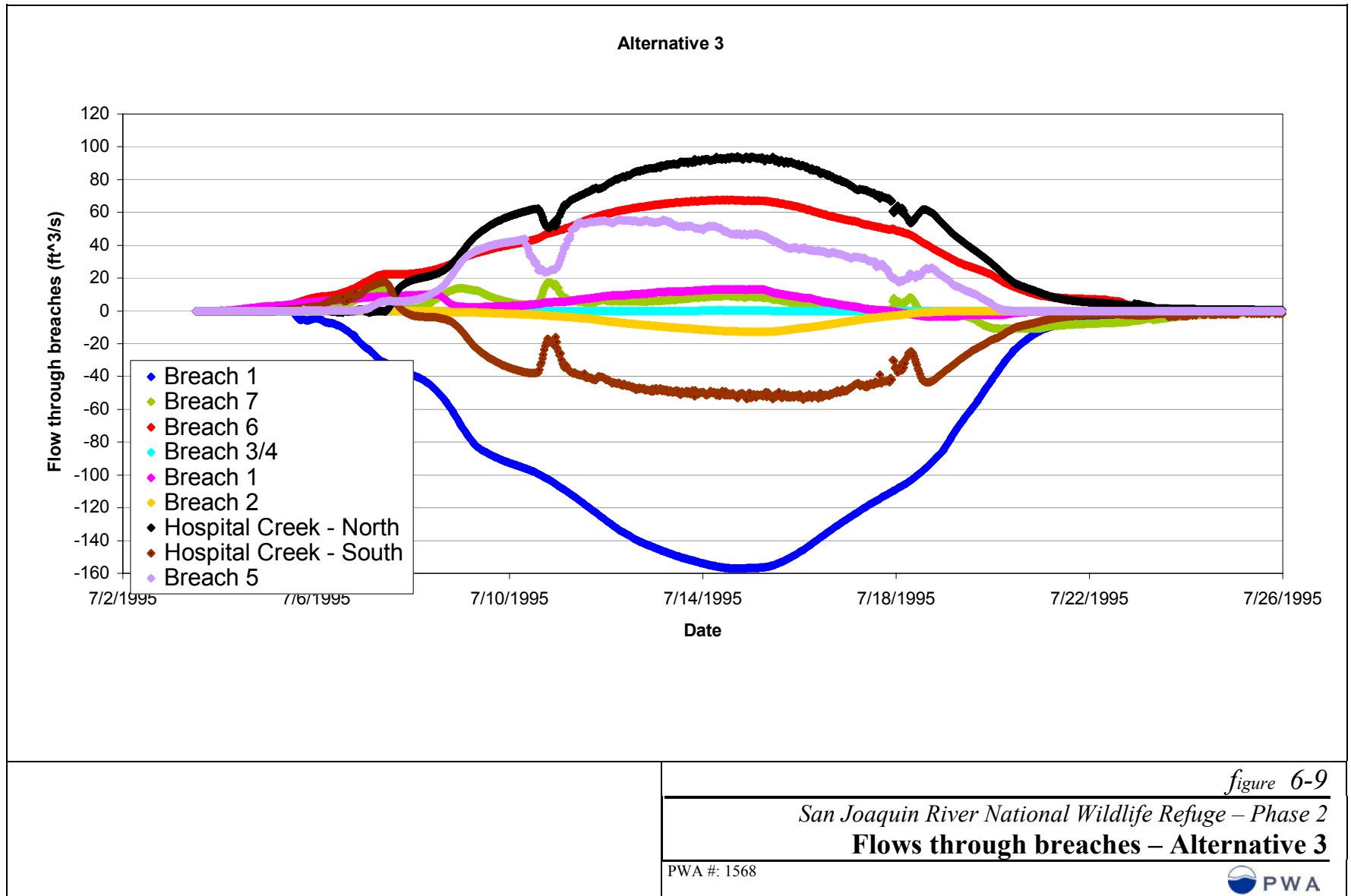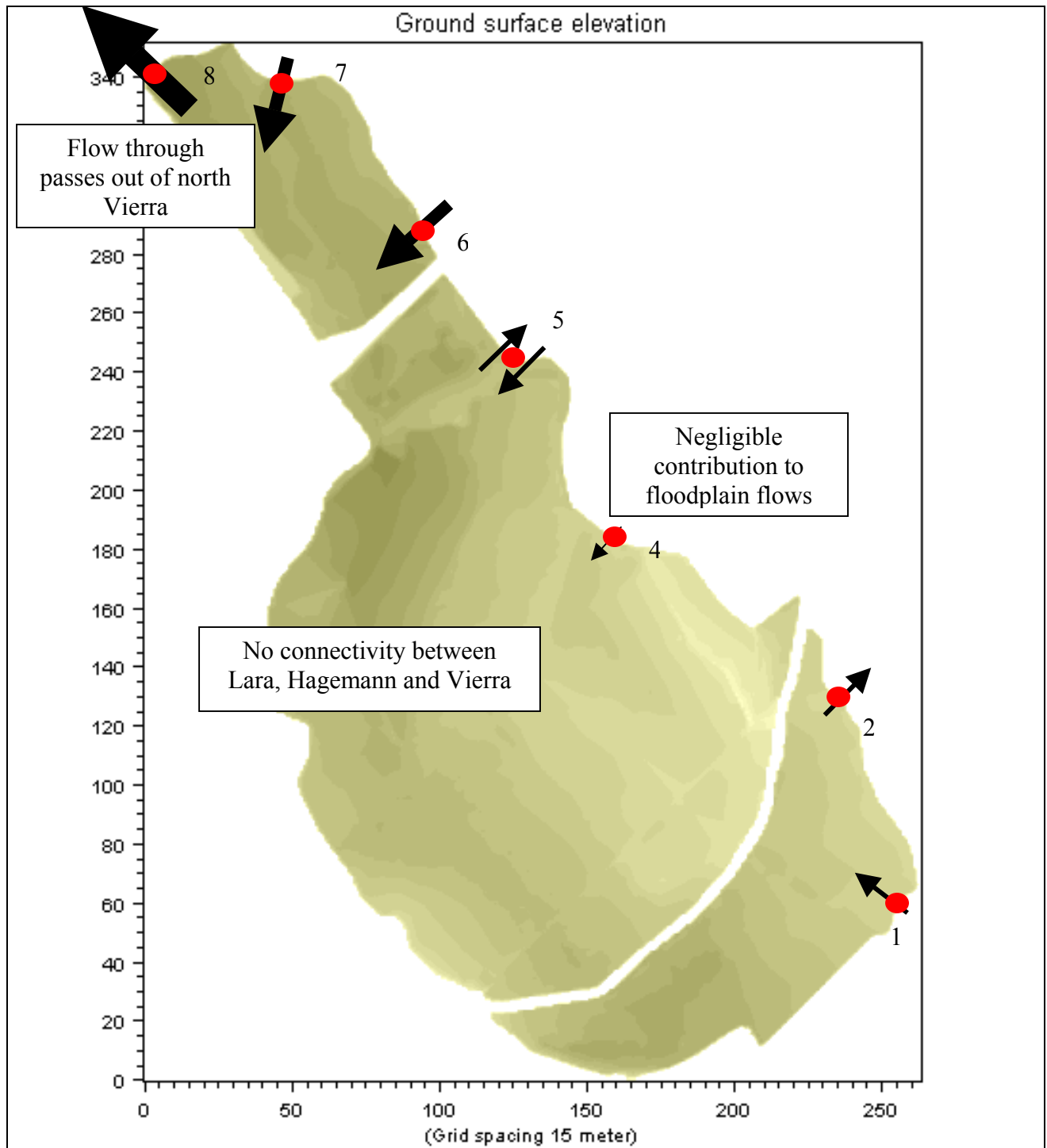
Alternative 3

Flow through breaches (ft^3/s)

Legend:
- Breach 1
- Breach 7
- Breach 6
- Breach 3/4
- Breach 1
- Breach 2
- Hospital Creek - North
- Hospital Creek - South
- Breach 5

Date

Ground surface elevation

Flow through passes out of north Vierra

Negligible contribution to floodplain flows

No connectivity between Lara, Hagemann and Vierra

(Grid spacing 15 meter)

Note: Size of flow arrows approximately relative to magnitude of total flows
Darker brown shades represent lower elevations

figure 6-10

San Joaquin River National Wildlife Refuge – Phase 2
Alternative 1 – Approximate flows through breaches
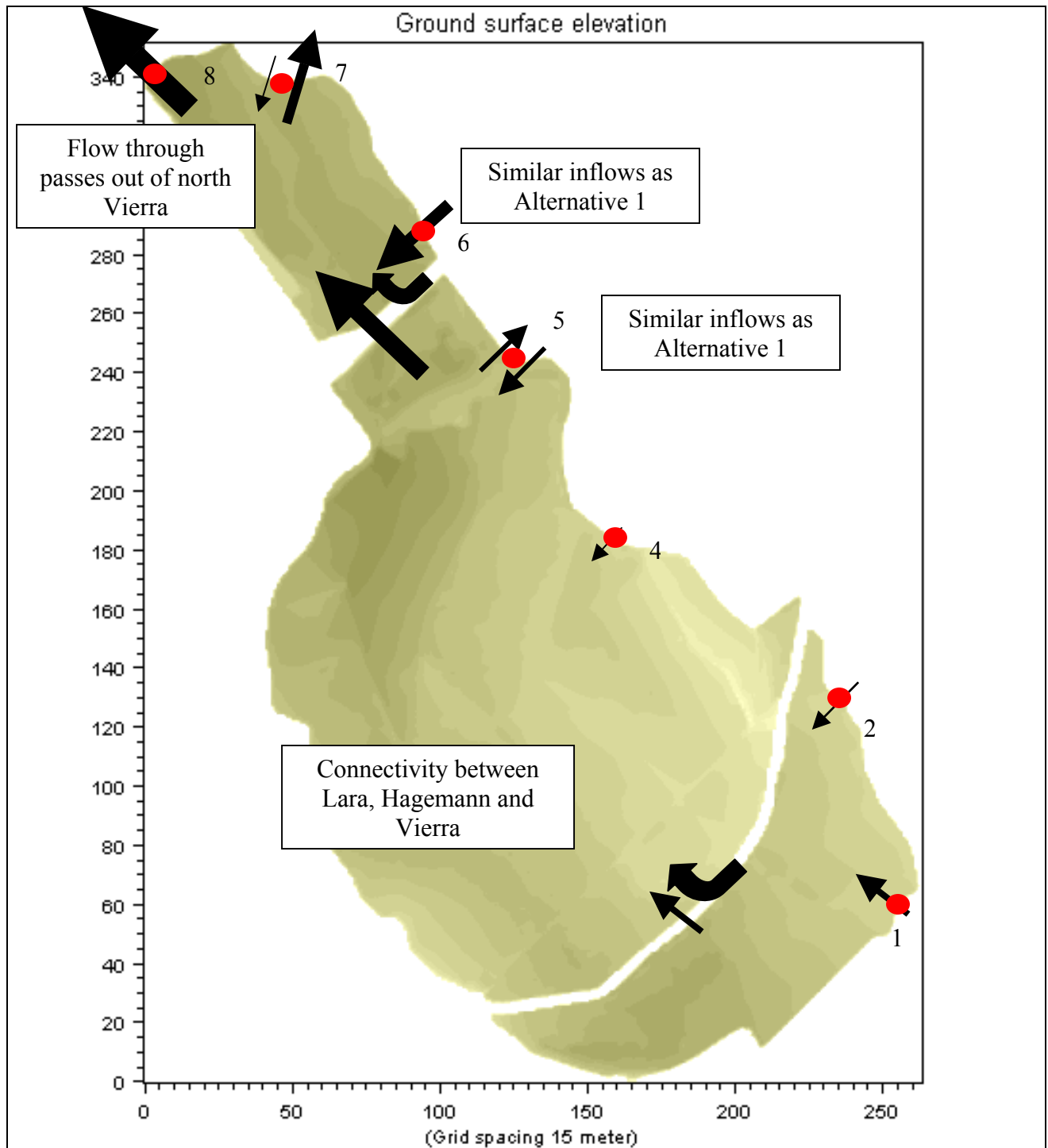
PWA #: 1646

PWA

figure 6-11

Note: Size of flow arrows approximately relative to magnitude of total flows

Darker brown shades represent lower elevations

San Joaquin River National Wildlife Refuge – Phase 2
Alternative 2 – Approximate flows through breaches

PWA #: 1646

PWA

Ground surface elevation

Flow through passes out of north Vierra

Similar inflows to Alternative 2

Similar contribution of flows to Vierra from Hospital Creek as Alternative 2

Flow through from Hagemann to Vierra

No connectivity between Lara and Hagemann

Identical infows and outflows as Alternative 1 for Lara

(Grid spacing 15 meter)

Note: Size of flow arrows approximately relative to magnitude of total flows

Darker brown shades represent lower elevations

figure 6-12

San Joaquin River National Wildlife Refuge – Phase 2
Alternative 3 – Approximate flows through breaches

PWA #: 1646

PWA

6.4   FLOOD DEPTH ON THE FLOODPLAIN

Figure 6-13 shows the sample locations discussed in this section. The results shown by Figure 6-14 to Figure 6-17 are summarized by Alternative in the following sections.

6.4.1   Alternative 1

1. The largest flooding depths occur on the floodplain at Hagemann north (H2) with a maximum depth of 13 feet.
2. The smallest flooding depths occur on the floodplain at Lara east (L2) with a maximum depth of 4 feet.
3. Maximum depths on Hagemann very between approximately 5 feet and 14 feet.
4. Maximum depths on Lara vary between approximately 4 feet and 11 feet.
5. Maximum depths on Vierra are approximately 8 feet.

6.4.2   Alternative 2

1. Connectivity between Hagemann and Lara through the West Stanislaus Canal results in earlier flooding in the south of Hagemann (H3 and H4) than in Alternative 1, but results in later flooding of east Lara (L2). This breach also reduces the maximum depth of flooding in east Lara by approximately 1.6 feet from 3.9 feet in Alternative 1 to 2.3 feet in Alternative 2, and by approximately 2.3 feet from 11.5 feet in Alternative 1 to 9.2 feet in Alternative 2 for Lara west (L1).
2. East Lara drains earlier as a result of connectivity between Hagemann and Lara through the West Stanislaus Canal.
3. Connectivity between Hagemann and Vierra through Hospital Creek results in earlier inundation of Hagemann north (H1 and H2) by approximately one day over Alternative 1. The connection through Hospital Creek also results in slightly earlier drainage than in Alternative 1.
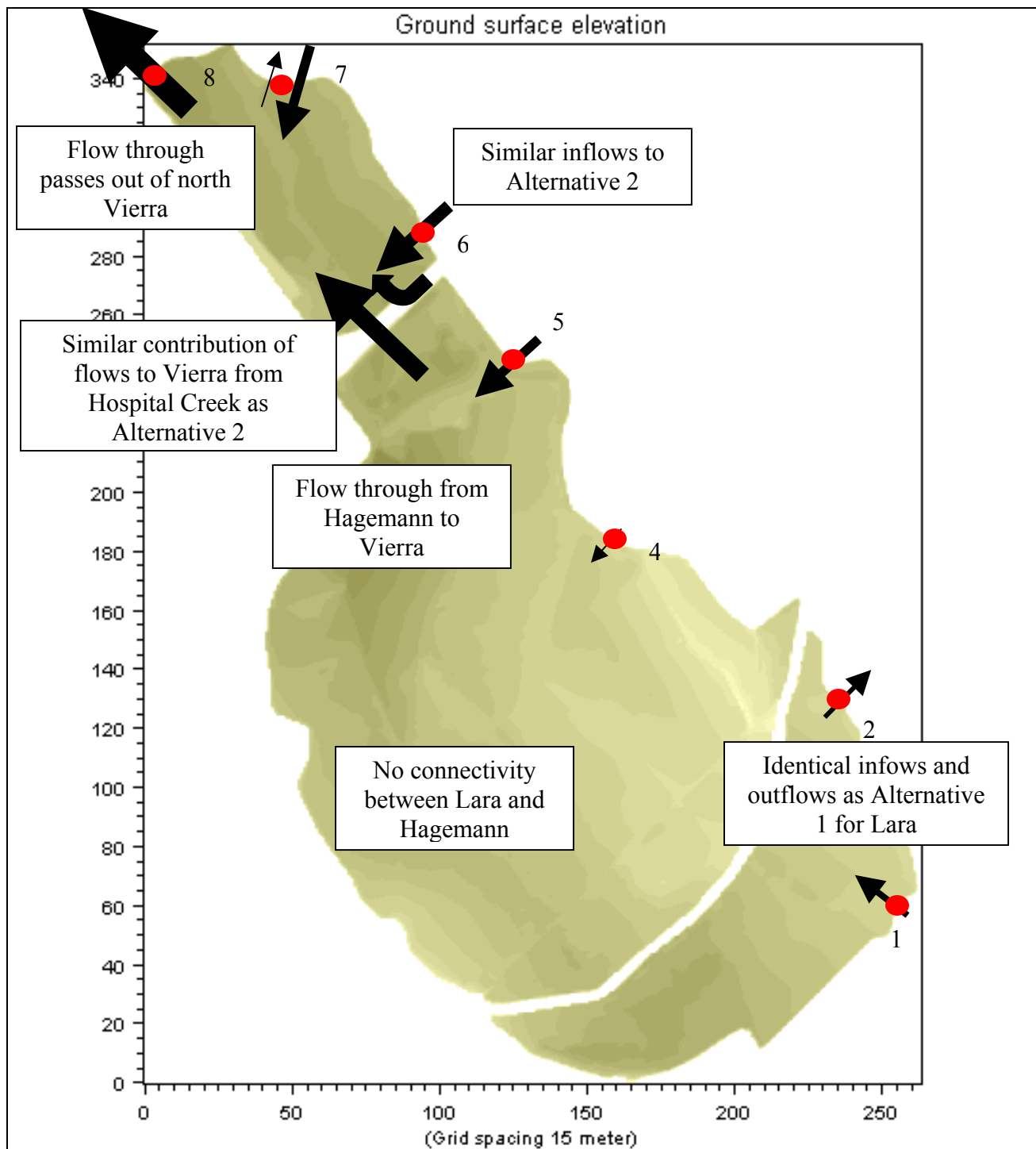4. Maximum depths in Vierra are mostly unaffected by connectivity between Hagemann and Vierra.
5. Maximum depths in Hagemann are mostly unaffected by the connections across Hospital Creek and the West Stanislaus Canal.

6.4.3   Alternative 3

1. Hagemann north (H1 and H2) drainage is improved in a similar manner as in Alternative 2 due to the connectivity between Hagemann and Vierra through Hospital Creek.
2. Hagemann north inundates at approximately the same rate and time as for Alternative 2.
3. Hagemann south (H3 and H4) inundates approximately two days later than in Alternative 2 due to the lack of connectivity between Lara and Hagemann through the West Stanislaus Canal. Maximum depths in Hagemann south are approximately the same as Alternative 2.
4. Maximum depths in Vierra are mostly unaffected by the connectivity between Hagemann and Vierra in comparison to Alternatives 1 and 2.

5. Maximum depths in Lara are similar to Alternative 1 due to the lack of connectivity between Lara and Hagemann.
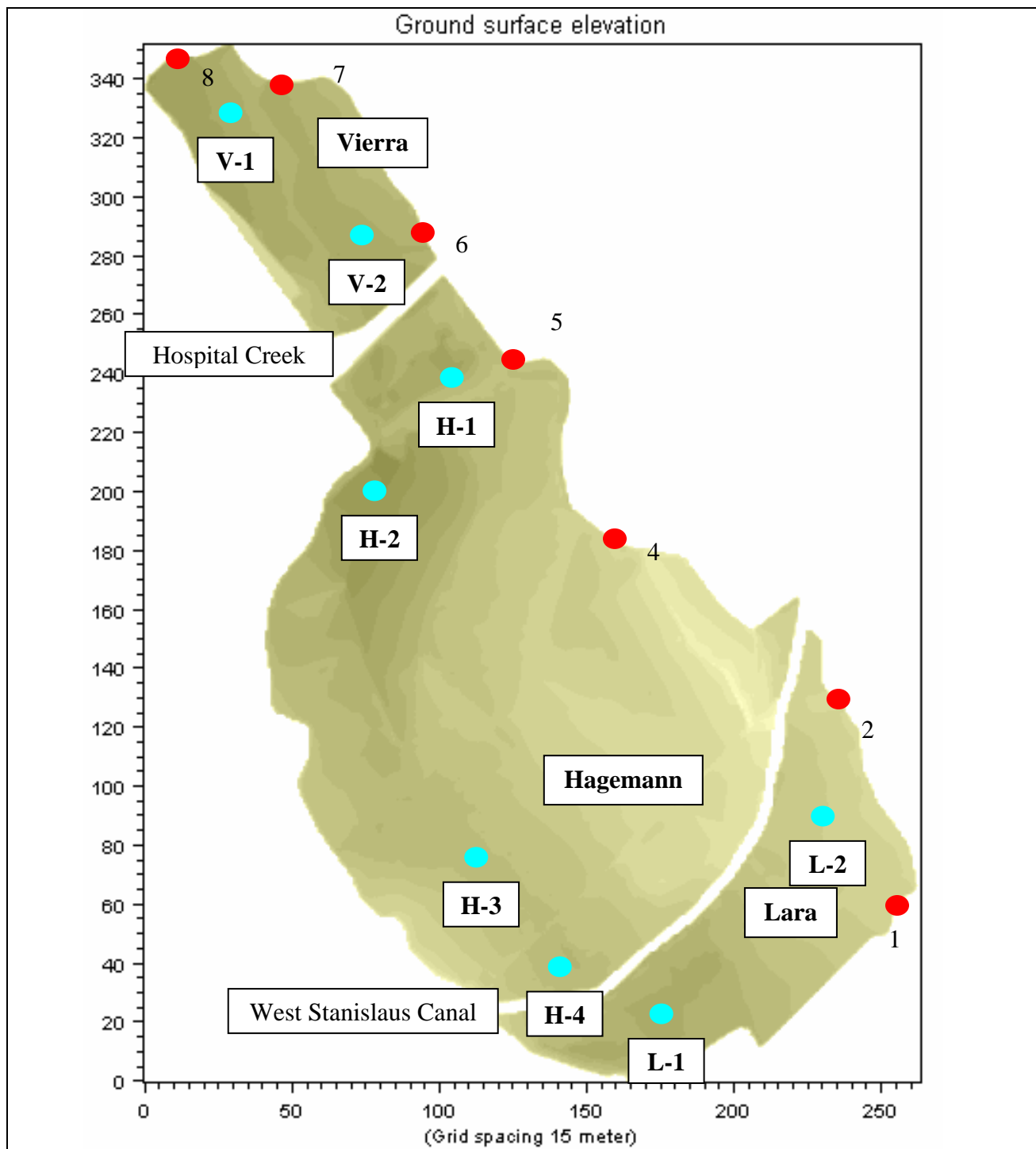
figure 6-13

San Joaquin River National Wildlife Refuge – Phase 2
Analysis location points

PWA #: 1568
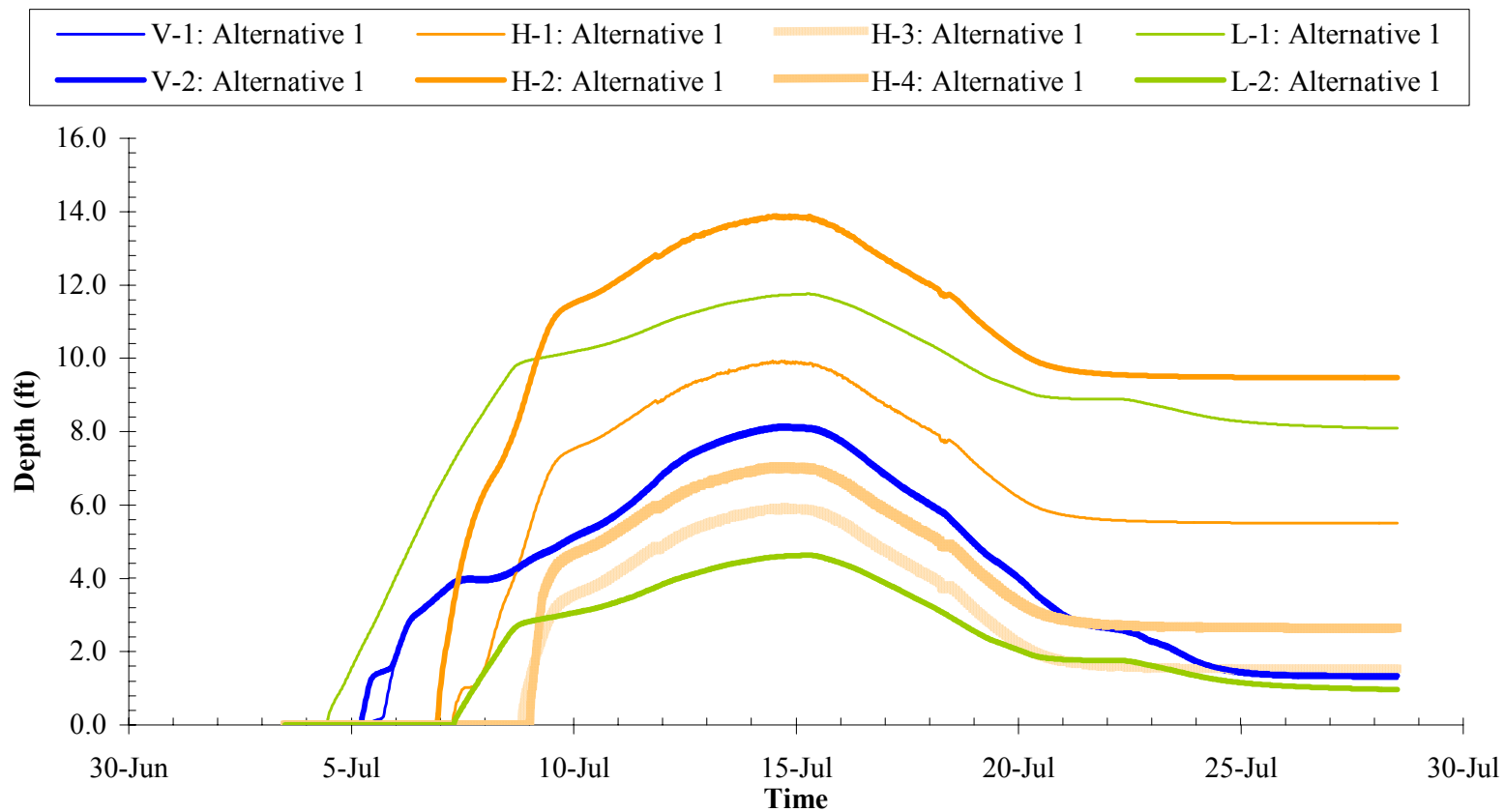
Source:

Source:

figure **6-15**

San Joaquin River National Wildlife Refuge – Phase 2

Alternative 2 – Depths on the floodplain

PWA #: 1568

PWA

Legend:
- V-1: Alternative 3
- V-2: Alternative 3
- H-1: Alternative 3
- H-2: Alternative 3
- H-3: Alternative 3
- H-4: Alternative 3
- L-1: Alternative 3
- L-2: Alternative 3

Depth (ft)

Time

Legend:
- L-1: Alternative 1
- L-1: Alternative 2
- L-1: Alternative 3
- H-2: Alternative 1
- H-2: Alternative 2
- H-2: Alternative 3
- V-2: Alternative 1
- V-2: Alternative 2
- V-2: Alternative 3

Source:

6.5   VELOCITY ON THE FLOODPLAIN

Relatively large velocities are present on Hagemann, Lara and Vierra at the start of inundation (up to 4.6 ft/s) that reduce dramatically as ponding occurs on the floodplain. During ponding on the floodplains of Hagemann and Lara, the velocities on the floodplains are negligible to minor for all three alternatives.

The results shown by Figure 6-18 to Figure 6-20 for floodplain velocities during ponding are summarized by Alternative in the following sections. Velocity point locations are shown on Figure 6-13.

6.5.1   Alternative 1

1. Flow-through velocities are present on Vierra even during ponding, with velocities generally varying from 0.7 ft/s to 2.0 ft/s.

6.5.2   Alternative 2

1. Connectivity between Hagemann and Lara through the West Stanislaus Canal results in small flow-through velocities in south Hagemann up to 0.7 ft/s.
2. Flow-through velocities on Vierra are similar in magnitude to Alternative 1.
3. Negligible velocities occur on Lara during ponding but unlike Hagemann and Vierra, high velocities (maximum of 4.5 ft/s) occur during drainage due to efficient flows through the West Stanislaus Canal.
4. Connectivity between Hagemann and Vierra through Hospital Creek results in higher flow-through velocities in Hagemann north than Alternative 1, up to 0.2 ft/s.

6.5.3   Alternative 3

1. Lower flow-through velocities result in this alternative on north Hagemann than for Alternative 2.
2. Negligible velocities result on south Hagemann since there is no connectivity between Hagemann and Lara.
3. Negligible velocities result on Lara.
4. Slightly greater flow-through velocities result on Vierra compared to Alternative 1 as a result of this alternative.
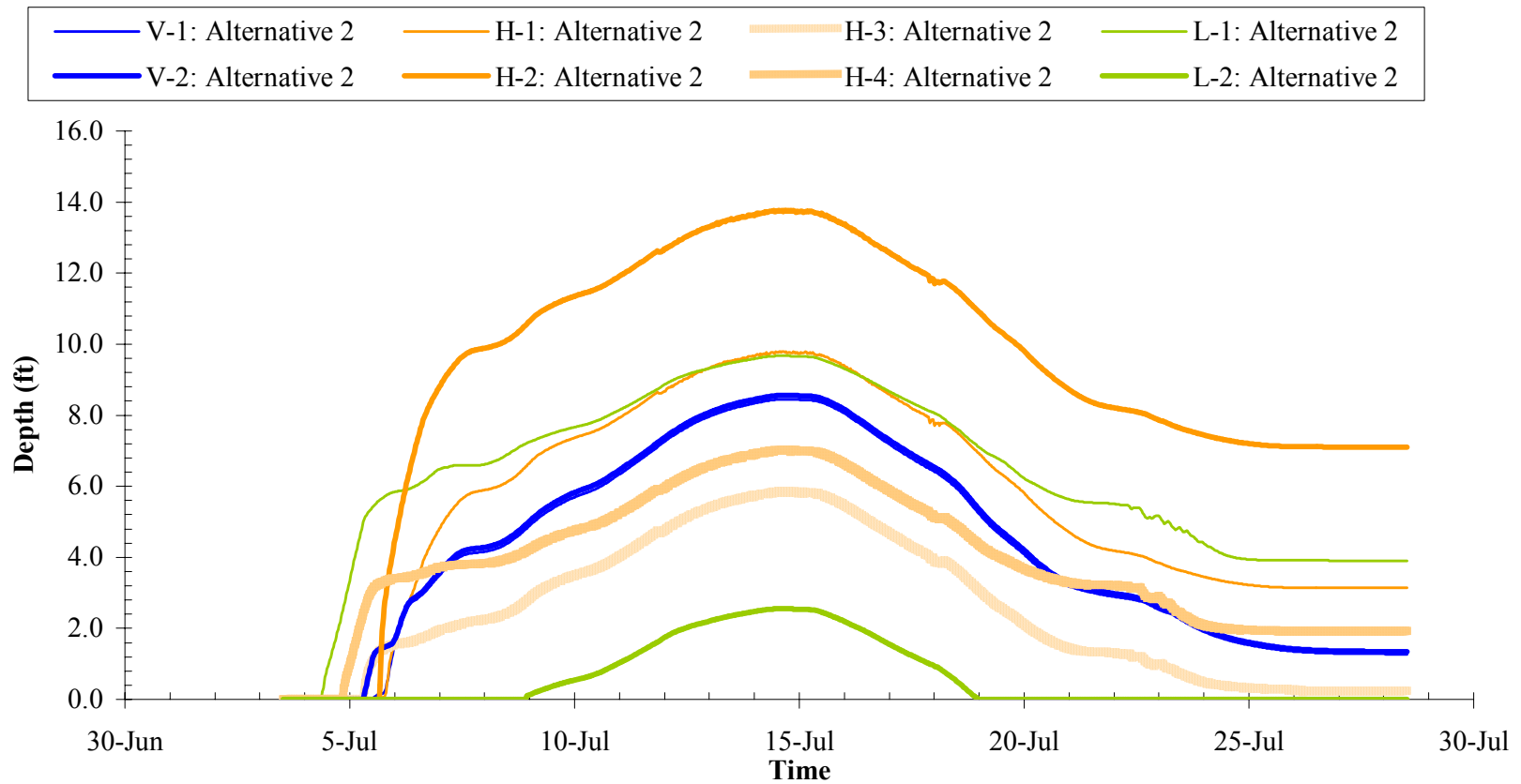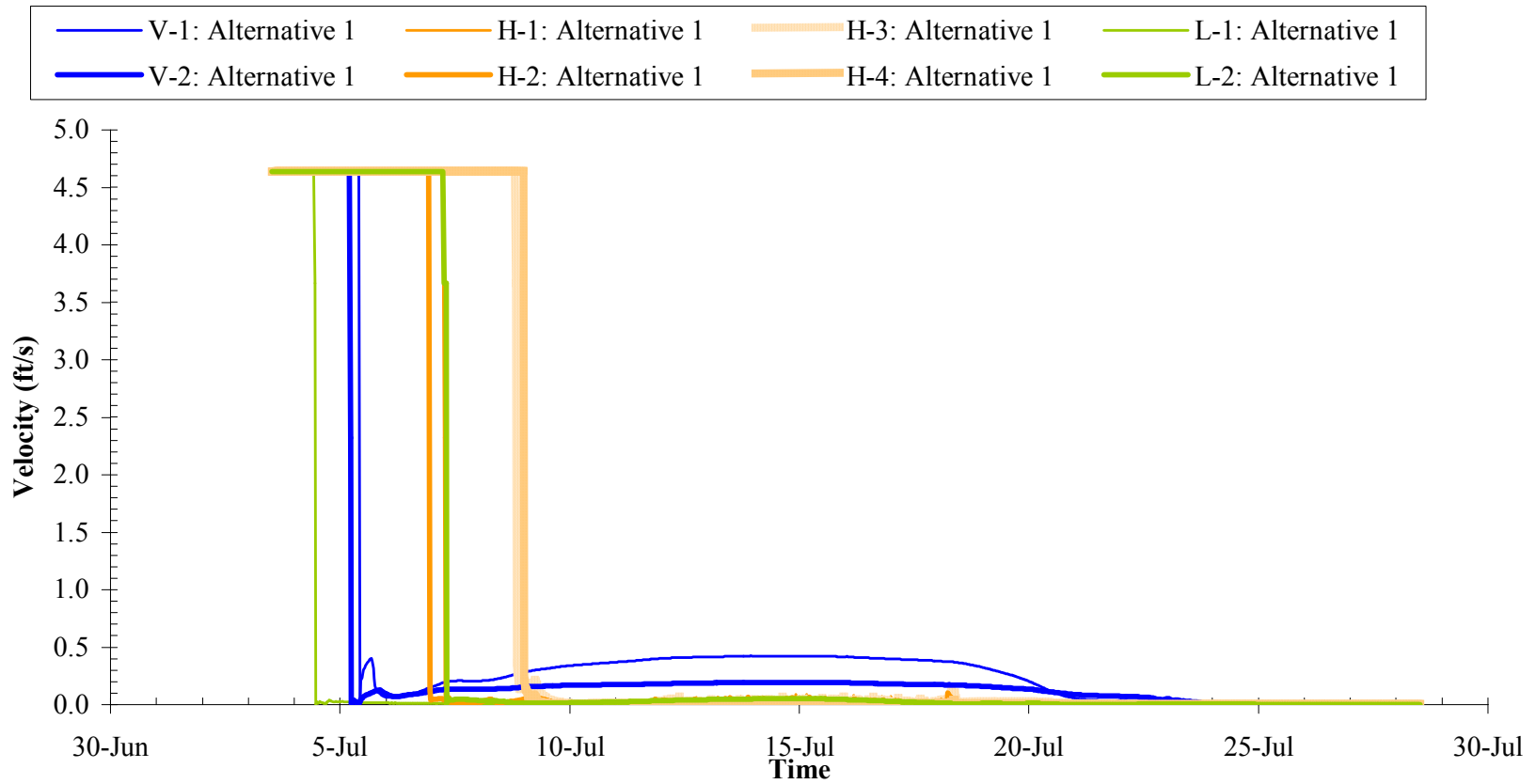
figure 6-18

San Joaquin River National Wildlife Refuge – Phase 2

Alternative 1 – Velocity on the floodplain
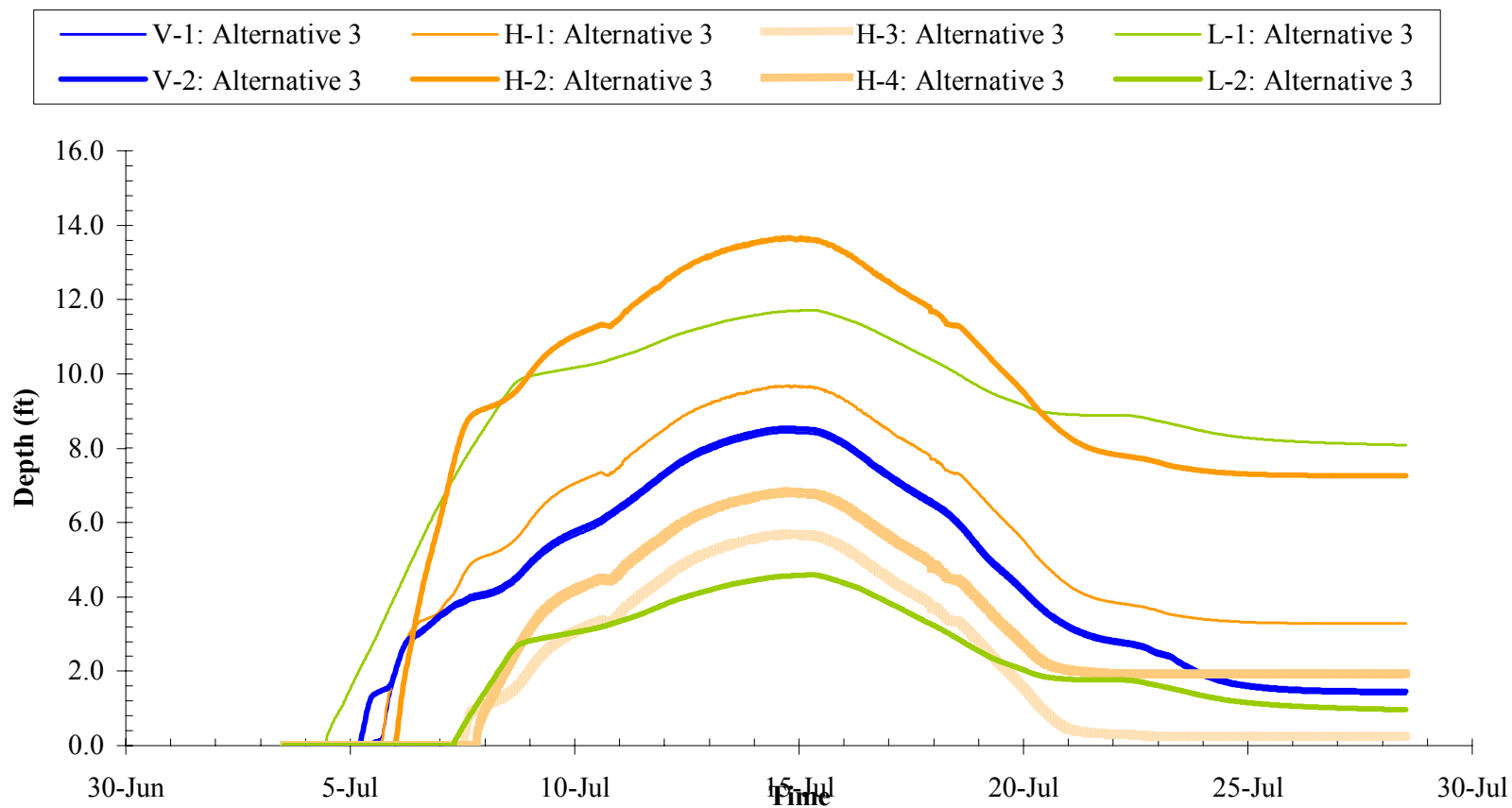
PWA #: 1568

PWA
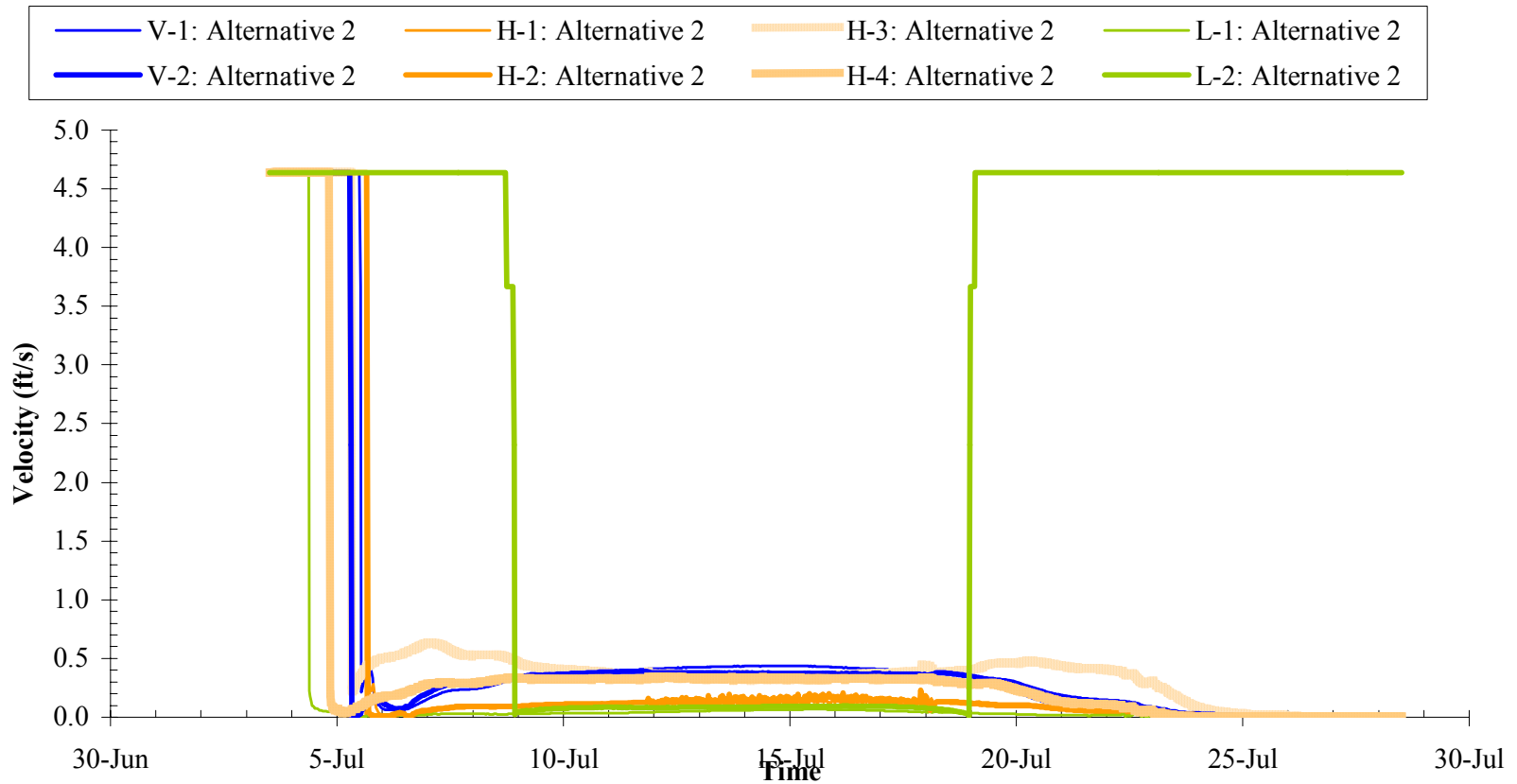
Source:

figure 6-19

San Joaquin River National Wildlife Refuge – Phase 2

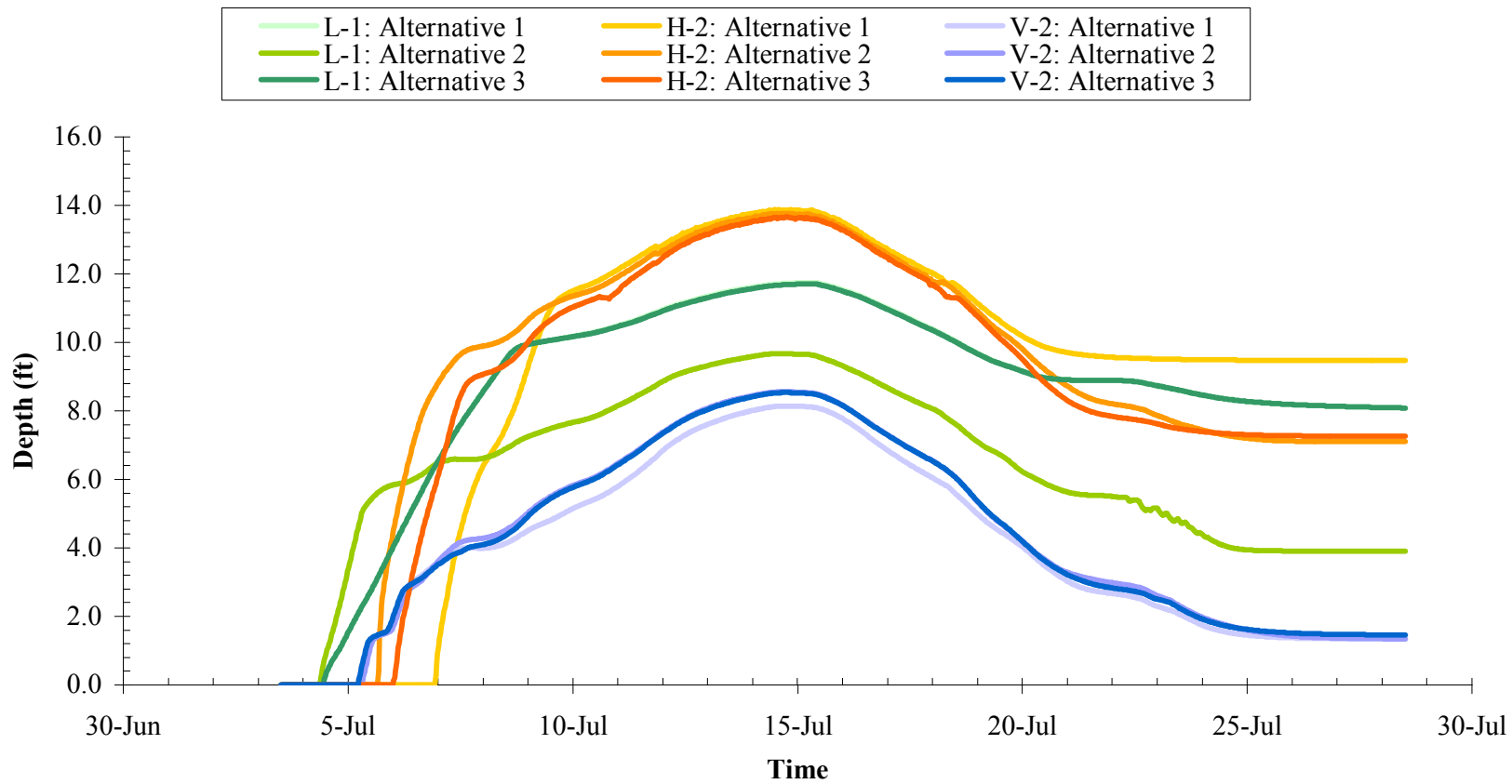**Alternative 2 – Velocity on the floodplain**
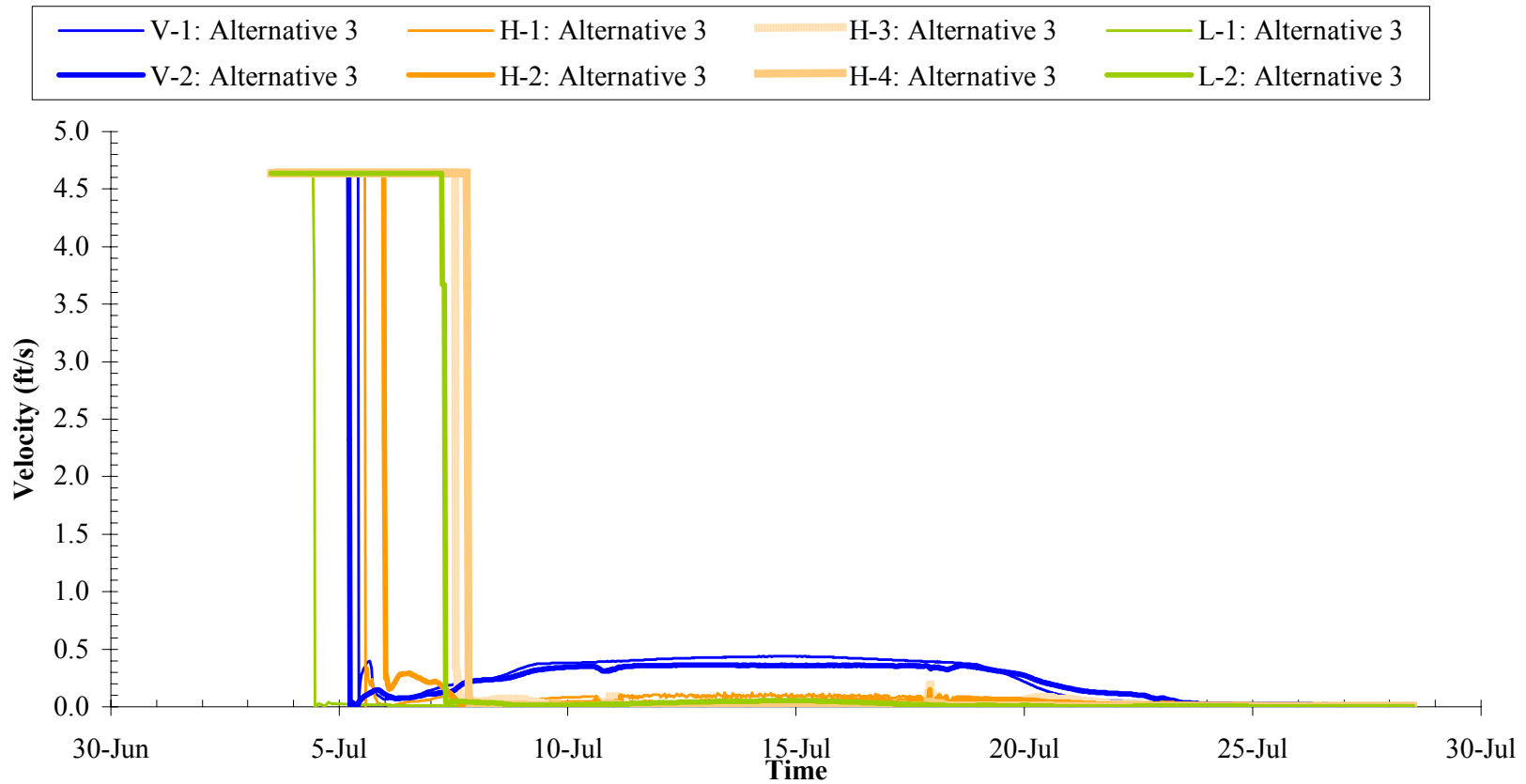
PWA #: 1568

PWA

Source:

6.6   EFFECTS OF LEVEE BREACHING ALTERNATIVES ON FLOWS IN THE SAN JOAQUIN
        RIVER

The SJRNWR represents approximately 3,100 acres of land that may be used for potential attenuation of flood flows. The USACE completed a preliminary investigation into the flood reduction benefits of the proposed NSA project in 1998. However, their findings concluded that the project had negligible benefit for flood storage and attenuation of flows when considering the San Joaquin River as a whole. Although an investigation into the flood reduction benefit as a result of the proposed alternatives was not an objective of this study, PWA extracted data from the model to further investigate the potential for attenuation of flows.

Figure 6-21 shows the hydrograph of the modeled event for each of the three alternatives at three locations on the San Joaquin River. One set of results are shown at the upstream end of the project reach, a second set of results are shown approximately at the middle of the project reach and the third set of results are shown from the downstream end of the project reach. The most significant finding of this figure is that Alternative 2 provides for the largest attenuation of flows. Alternatives 1 and 3 have negligible effect in terms of attenuation of flows.

The influence of attenuation of flows on the floodplain of the SJRNWR is shown in Figure 6-22. This figure shows the water surface profiles in the San Joaquin River through the project reach for the three alternatives. It can be observed that the maximum decrease in water surface elevation of approximately 0.3 feet is obtained compared to the base condition (Alternative 1) with Alternative 2. This reduction in water surface elevation is probably only local and may be negligible in terms of flood reduction compared to the No Project condition (not modeled). However, it does indicate that a lower peak stage is achieved by Alternative 2 than Alternatives 1 or 3.

San Joaquin River at downstream end of project reach
(Maze Rd Bridge)

San Joaquin River in
middle of project reach

Effect of Alternative 2 on San Joaquin
River flows in the project reach

San Joaquin River at
upstream end of project reach

Alt 1
Alt 2
Alt 3

Discharge (cfs)

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0

30-Jun   5-Jul   10-Jul   15-Jul   20-Jul   25-Jul   30-Jul

Time
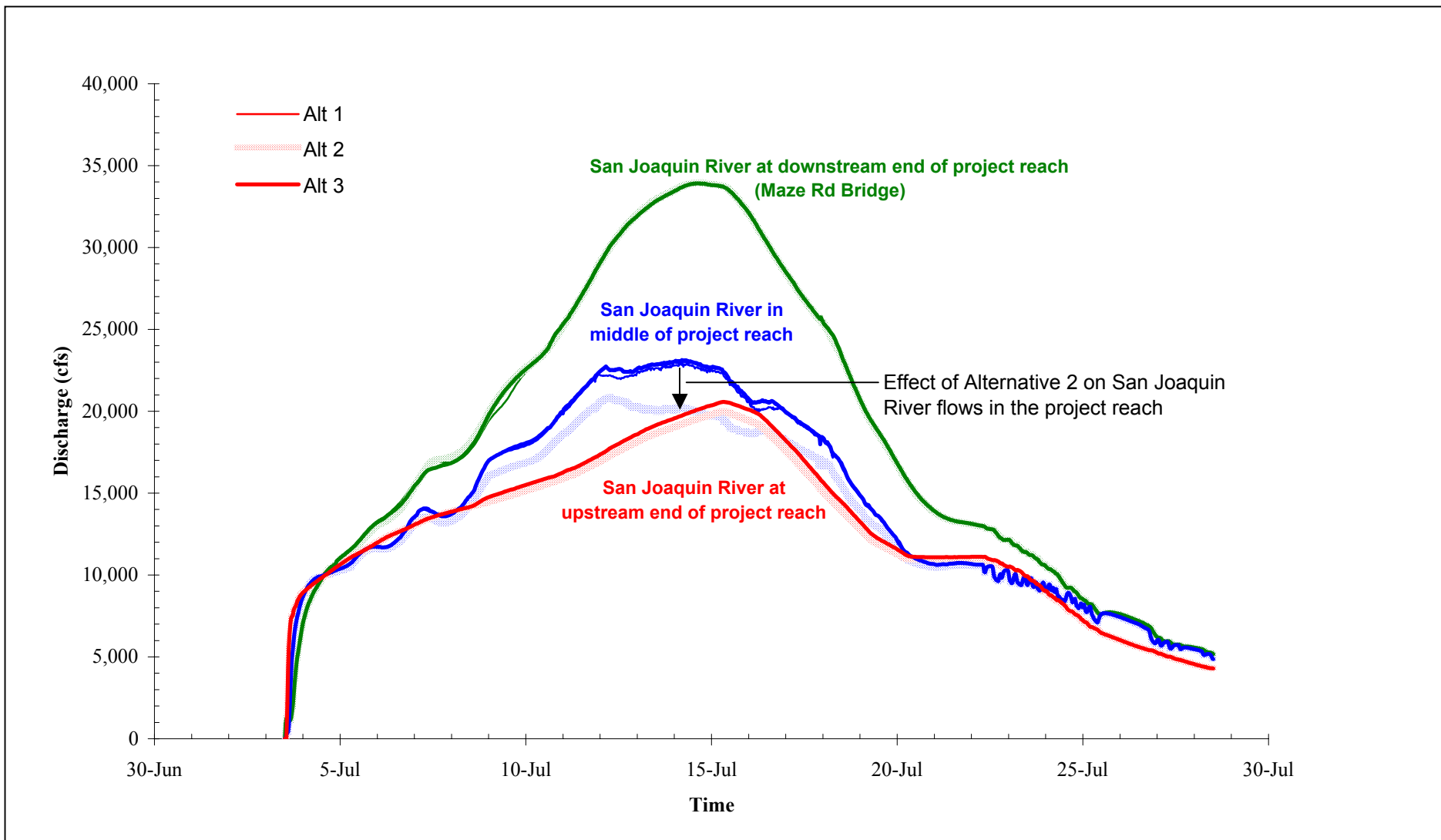
San Joaquin Riuer National Wildlife Refuge - Phase 2

San Joaquin River 10-year Water Surface Profiles for 3 Alternatives

figure *6-22*
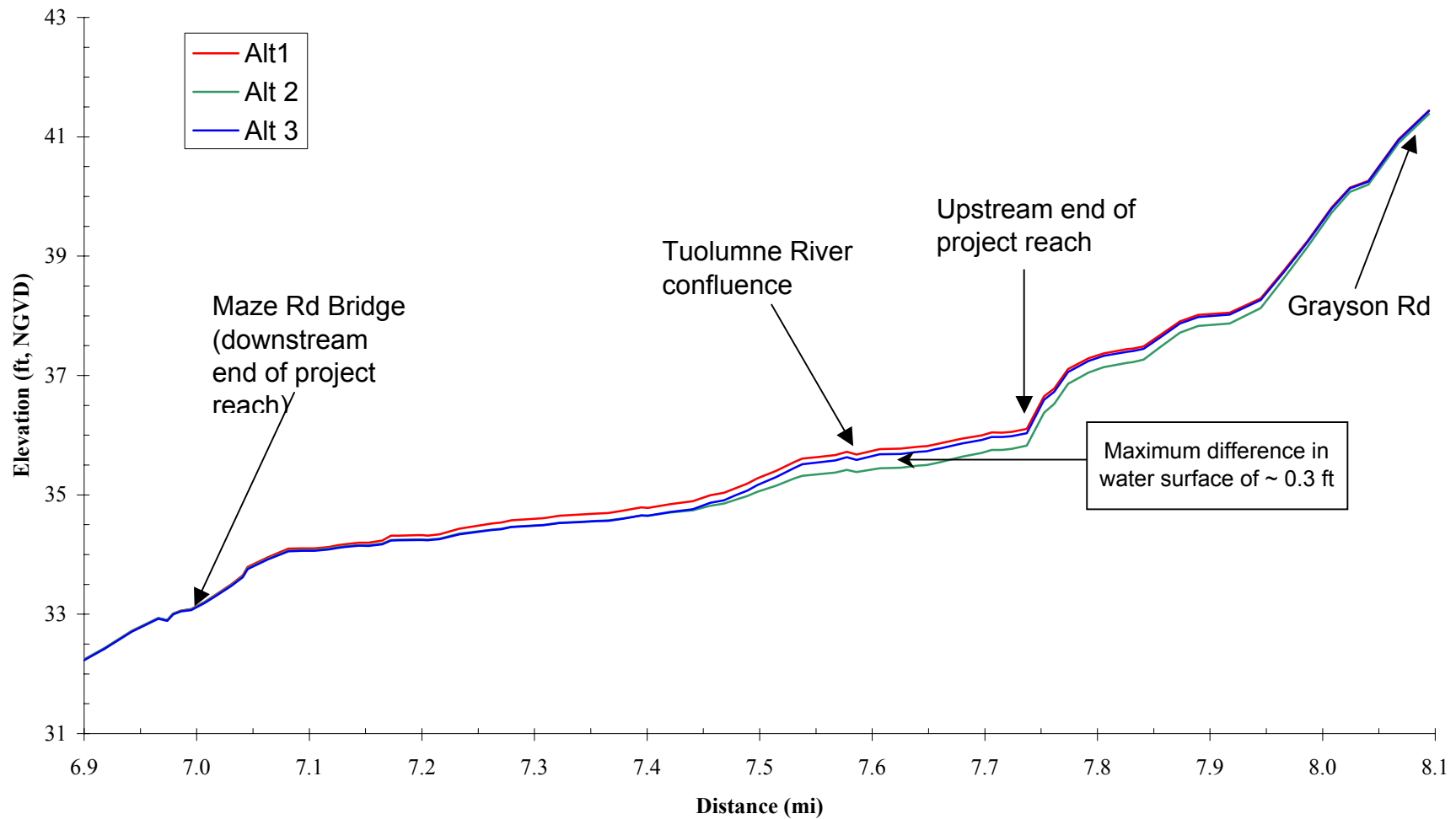
PWA Ref 1568.00

Notes: MIKEFLOOD model results
Source: Runs Alt1-1~, Alt2-1~, Alt3-1~

6.7   KEY ATTRIBUTES OF SITE FUNCTION UNDER ALTERNATIVE SCENARIOS

This section provides a summary of the key attributes of each alternative. Following each sub-section a hyper-link is provided to animations showing the inundation process for each alternative that can only be viewed in electronic versions of this document.

6.7.1   Alternative 1

1. Lara inundates first, then Vierra, lastly Hagemann.
2. All basins inundate rapidly.
3. Beneficial flow-through velocities exist on Vierra.
4. Hagemann operates almost as a backwater with inflows and outflows only passing through one breach (5). Very poor flow-through velocities are present on Hagemann.
5. Some limited magnitude of flow-through velocity is present on Lara. Flows pass into the floodplain through Breach 1 and out of floodplain through Breach 2.
6. Depths can reach up to 12 feet on Hagemann and Lara.
7. Slow drainage occurs during the receding limb of the hydrograph, particularly on Lara.

Click here (electronic version of the document only) to see animation of this alternative. Note the velocity vectors in the animation which give an indication of the direction and magnitude of the flow passing through the floodplain.

6.7.2   Alternative 2

1. Lara inundates first, then Hagemann from the south, lastly Vierra.
2. All basins inundate rapidly.
3. Beneficial flow-through velocities are maintained on Vierra.
4. Highly improved flow-through velocities on Hagemann and Lara exist due to connectivity across West Stanislaus Canal and Hospital Creek.
5. Greatly improved drainage exists on all basins due to connectivity between parcels.
6. Maximum depths on the floodplain are reduced from Alternative 1.

Click here (electronic version of the document only) to see animation of this alternative.

6.7.3   Alternative 3

1. Lara inundates first, then Vierra and lastly Hagemann which inundates first from Hospital Creek then from Breach 5.
2. All basins inundate rapidly.
3. Beneficial flow-through velocities are maintained on Vierra.
4. Improved flow-through velocities exist on Hagemann north over Alternative 1 but still poor flow-through velocities exist on Hagemann south.

5. Hagemann does not act so much as a backwater as for Alternative 1.
6. Improved drainage exists on Hagemann over Alternative 1 but poor drainage on exists Lara (similar to Alternative 1).

[Click here (electronic version of the document only) to see animation of this alternative.](#)

Generally, the West Stanislaus Canal acts primarily as a drain rather than a source of flood water. Hospital Creek primarily provides early flooding rather than improved drainage. Alternative 2 may have the least likelihood of fish stranding issues since flow-through velocities are maintained through the whole SJRNWR. Issues relating to the planned connections through the West Stanislaus Canal and Hospital creek may present operational or permitting issues. However it should be noted that the berms that presently exist on the West Stanislaus Canal are not engineered levees. The material that makes up these berms consists mainly of dredged material from historical maintenance of the canal. Therefore, breaching of these berms will likely occur naturally over time if any of the alternatives are implemented. The project levees that bound Hospital Creek will be subjected to the same jurisdictional requirements imposed by the USACE for the project levees that bound the eastern boundary of the SJRNWR.

All the breaches except breach 4 function effectively at the minor flood level simulated. Breach 4 conveys negligible flow volumes for the event modeled in this study. This is primarily due to the higher elevation of the floodplain at this location in comparison to the other planned breaches. However, it is likely that at larger recurrence interval flows this breach would become more effective. If funding permits, it would be advisable to include this breach in the design plans to provide for more effective inundation of topography at a higher elevation during larger events. In such circumstances Breach 4 would also provide for improved flow-through velocities in the vicinity of the floodplain.

Finally, areas of concentrated, high flows, especially during drainage, are likely to experience the greatest morphological change over time as a result of the project. Therefore, it should be expected that the breaches will likely change in morphology with each floodplain flow event. In addition, increased scour of both Hospital Creek and the West Stanislaus Canal may be expected as a result of project implementation.

6.8   IMPLICATIONS OF MODEL RESULTS FOR HABITAT VALUE

The physical results of this study have been compared to the habitat evaluation criteria formulated in Phase 1 and listed again here in Table 6-4.

In terms of inundation area, the depth criteria listed in Table 6-4 suggested depths most beneficial for fish between 6 inches and 6 feet. Therefore the model results were analyzed accordingly with the following results.

Figure 6-23 shows total area-duration curves for the three alternatives for flow depths on the floodplain between six inches and six feet. These depth criteria were selected by the panel of fish biologists who were queried to develop the habitat evaluation criteria matrix formulated in Phase 1 of the project and

shown in this report by Table 6-4. Figure 6-23 also shows the hydrographs in the San Joaquin River at the upstream and downstream extents of the model for comparison purposes. The results shown by this graph can be summarized as follows:

1. Alternative 1 inundates to the largest maximum acreage of approximately 1,200 acres.
2. Alternative 1 drains the least rapidly of all three alternatives.
3. Alternative 2 and 3 inundate to approximately the same maximum acreage of approximately 1,120 acres.
4. Alternative 2 inundates and drains the most rapidly of all the alternatives. This alternative reaches an inundation of approximately 800 acres almost two days earlier than Alternative 1 and almost one day earlier than Alternative 3.
5. At least 1,000 acres is inundated for approximately twelve days for the event modeled for all three alternatives.
6. For all three alternatives the area of inundation between 6 inches and 6 feet reduces at the peak of the hydrograph in the San Joaquin River. This is because the area calculation excludes those areas of the floodplain that are inundated to a depth greater than six feet.

As part of this study, an attempt was made to rank the alternatives based on criteria defined in Table 6-4 and other criteria not related to habitat. Table 6-5 shows a ranking scheme that was applied to the alternatives whereby each criterion was ranked from 1 to 3 for each property in each alternative. A rank of 1 represents the least beneficial effect relative to the criteria; a rank of 3 represents the most beneficial effect on the criteria. It should be noted that no weights have been assigned to the criteria in this study, and this ranking is merely provided to assist the reader; it has not been endorsed by any stakeholder group.

Table 6-4 Summary of habitat evaluation criteria (PWA, 2001)

Parameter	Value	Species	Biological Importance
Recurrence Interval	Minimum 2-3 year return period[1]	Splittail	Ensure adequately-frequent spawning
Timing of flooding	Late February →April[1,2,3, 6]	Splittail	principal spawning and rearing months
	May[1,3,6]	Splittail	Spawning and rearing may extend into May
	December →May[1, 7]	Chinook salmon	Rearing habitat for juveniles
	Prior to February[1]	Splittail	May increase habitat value by providing additional forage habitat for adults
	December →May[4]	Phytoplankton Zooplankton	Improved production prior to arrival of juvenile and adult salmon, splittail
Duration of flooding/Mean Hydraulic Residence Time	≥ 2 days[4]	Phytoplankton	Improved production
	14 days – several weeks[2,4]	Zooplankton	Improved production
	≥ 14 days[3, 6]	Splittail, chinook salmon	Adult spawning, incubation and larvae to develop sufficiently to move with receding flow
End of Inundation; connectivity	Avoid non-draining floodplain with depressions greater than 1 feet in depth[1]	Non-native fish	Avoidance of predator or non-native fish and reduction of salmon and splittail stranding.
Velocity and depth	Mean velocity: >0[2,4], < 3 ft/sec[7]	Splittail Chinook salmon	Adult splittail spawning in faster water, juvenile splittail use of slower water; salmon rearing only in moving water; both need flow cues to avoid stranding
	Total surface area between 6 inches and 6 feet depth[2,3,4]	Splittail Salmon	Splittail spawning, splittail and salmon habitat [1,2]

[1] Jones & Stokes Associates. 2000. Functional Relationships for the Ecosystem Functions Model, Sacramento-San Joaquin Rivers Basin Comprehensive Study. Final. (J&S F022). December. Sacramento, CA. Prepared for Sacramento-San Joaquin Rivers Basin Comprehensive Study Team, U.S. Army Corps of Engineers, Sacramento, CA.

[2] Keith Whitener, Project Ecologist, Cosumnes River Preserve, 2001. Personal communication.

[3] Randy Baxter, CA Department of Fish and Game, 2001. Personal communication.

[4] Ted Sommer, Environmental Specialist, CA Department of Water Resources, 2001. Personal communication.

[5] Jones & Stokes, 1999. Use of Restored Floodplain Habitat on the American River by Juvenile Chinook salmon and other Fish Species. June. Prepared for the Sacramento Area Flood Control Agency, Sacramento, CA.

Table 6-5 Ranking for alternative assessment

Alternative	Parcel	Frequency	Area and duration	Flow Patterns	Depth	Velocity	San Joaquin River	Impacts to West Stanislaus Canal	Total Score
1	Lara	3	2	3	1	1	1	3	**14**
1	Hagemann	1	2	3	1	1	1	3	**12**
1	Vierra	2	2	1	1	1	1	3	**11**
Total points for Alternative 1									**37**
2	Lara	3	3	2	3	3	3	1	**18**
2	Hagemann	2	3	1	3	3	3	1	**16**
2	Vierra	1	3	2	3	3	3	1	**16**
Total points for Alternative 2									**50**
3	Lara	3	1	3	1	1	2	3	**14**
3	Hagemann	1	1	2	2	2	2	3	**13**
3	Vierra	2	1	3	2	2	2	3	**15**
Total points for Alternative 3									**42**

Notes:

Frequency = frequency of inundation of inundation on floodplain of refuge.

Area and duration = area and duration of inundation on floodplain of refuge.

Flow patterns = flow patterns of inundation on floodplain of refuge.

Depth = depth of inundation on floodplain of refuge.

Velocity = velocity of inundation on floodplain of refuge.

San Joaquin River = impacts regarding reduction of flood stage to San Joaquin River (all alternatives minor).

The results summarized in Table 6-5 are described below.

1. The breaches on Lara are highly beneficial for floodplain inundation since Lara inundates at the lowest recurrence interval flow (2.0-year). Therefore, it is likely that Lara will be the most frequently used floodplain habitat and future restoration activities should recognize this expectation.

2. Alternative 2 is slightly more preferable in terms of more frequent floodplain inundation, though this benefit occurs primarily only on Hagemann.

3. For total area of inundation for depths between six inches and six feet, Alternative 1 provides the largest area, closely followed by Alternative 2; however, Alternative 2 provides a longer duration of inundation.

4. In Alternative 3, Hospital Creek, and in Alternative 2, the West Stanislaus Canal and Hospital Creek, contribute significantly to water and sediment fluxes between the river and floodplain.

5. Depths on the floodplain most beneficial to floodplain habitat (i.e., between 6 inches and 6 feet in depth) persist for the longest time in Alternative 2 (though for a smaller area than Alternative 1).

6. For the modeled flood, velocities on the floodplain, and hence through-flows on the floodplain, are most likely to minimize fish stranding in Alternative 2. Fish stranding issues may be least

8. Alternative 2 may have the greatest impact to the West Stanislaus Canal in terms of altering the flow regime in the canal during flood events. In terms of positive benefits, the altered flow regime in the canal under Alternative 2 may provide for increased scour potential in the canal during flood events, particularly in the receding limb of the hydrograph. Presently, the canal acts as a backwater during flood events. This would typically cause a canal to accrete with sediment over time; the regular dredging reportedly required of this canal to maintain irrigation flows suggests that such is the case here.
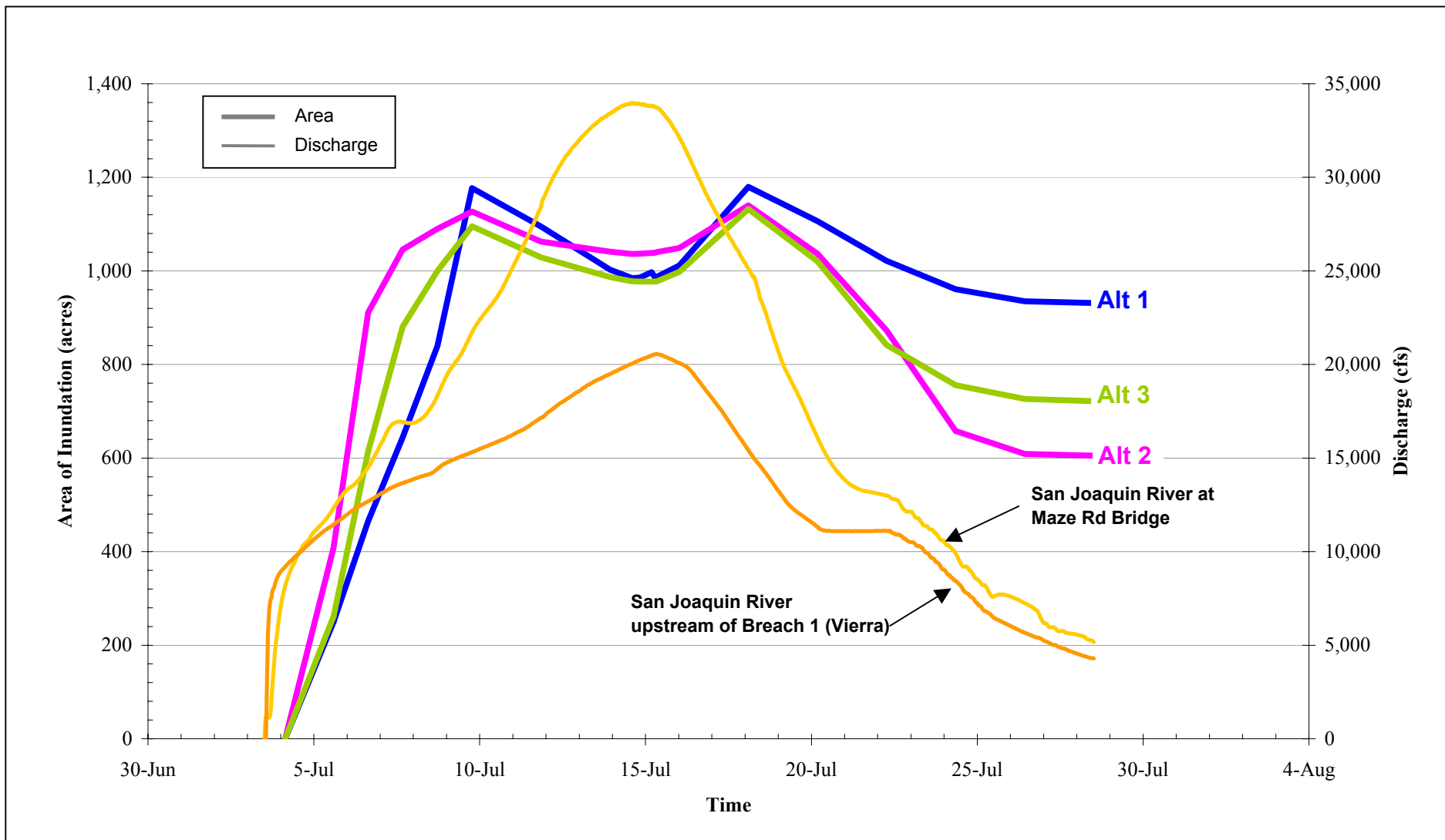
Area-duration curves for flood depths between 6 inches and 6 feet

7. PHYSICAL PROCESS INPUT INTO POST-PROJECT MONITORING PLAN

One of the primary goals of the SJRNWR non-structural flood management alternative is to restore floodplain/shallow water habitat for the benefit of anadromous and other native fishes. Native fish species expected to benefit from the SJRNWR restoration include Chinook salmon (candidate for federally threatened species) and splittail (federally threatened until September 2003). Ongoing, post-project monitoring can lead to a better understanding of habitat use by birds, fish, reptiles and mammals and the relationship of measurable physical indicators to species health. Post-project monitoring is the key tool for resource managers in applying an adaptive management program. Adaptive management is a systematic process for continually improving resource management policies by learning from the outcomes of implemented restoration projects.

This section describes the post-project physical process monitoring plan for the SJRNWR, including physical parameters, monitoring tasks, and expected costs. Monitoring programs for the SJRNWR regarding vegetation, birds, mammals, reptiles, and fish have been developed by the U.S. Fish and Wildlife Service and others and are under separate cover. Physical process monitoring data may be used in conjunction with biological monitoring data, such as to establish a correlation between fish use and habitat characteristics; however, the physical process monitoring plan has been designed to function independently of other monitoring programs.

We propose the following goals for physical processes monitoring at the SJRNWR:

1. To characterize physical process characteristics of habitat conditions resulting from the project, for the purpose of gauging the benefits and success of the project.
2. To describe the geomorphic evolution of the site, for the purpose of learning about the evolution of this example of a breached levee floodplain restoration site.

7.1   MONITORING AND MONITORING PARAMETERS

This section addresses the physical parameters required to evaluate the success of the project in improving habitat conditions for native anadromous fishes, and the evolution of floodplain and main channel geomorphology as a result of the levee breaches and other modifications to the floodplain. Monitoring of physical parameters associated with habitat may provide essential information to determine the need for and nature of desirable adaptive management project modifications for improved project function. It will also provide useful indicators of project success in providing beneficial floodplain habitat for anadromous fish. Monitoring of site evolution may be of some benefit for adaptive management, but primarily will be of interest in learning more about the nature and rate of change at breached levee floodplain restoration sites, particularly those adjacent to the San Joaquin in the vicinity of the project site.

7.1.1   Habitat Conditions

Physical parameters associated with habitat conditions include the following:

1. Surface water flow: depth, duration, timing, velocity, flow patterns, ponding

2. Surface water quality: temperature

3. Groundwater: depth below ground surface

Recommended monitoring approaches for each of these parameters are addressed below. The data collected through this monitoring effort should be provided annually to at least the staff of the SJRNWR and those responsible for the biological monitoring of the project site.

7.1.1.1   Surface Water Flow

Monitoring of surface water flow on the floodplain will be seasonal, and will require either the installation of automated monitoring equipment or the routine presence of field personnel during flooding events. To establish a record of floodplain flow occurrence we recommend automated stage recording (e.g., by means of a pressure transducer and data logger) at multiple locations for at least 10 years for the purpose of establishing the relationships between river stage and the floodplain inundation. Depth and areal extent can be established by relating this profile to the surface topography of the site. Relating stage at the project site to stage and discharge at or near Maze Road Bridge, a gauging site maintained by DWR less than two miles downstream, will allow the frequency and extent of floodplain inundation to be estimated from the flood frequency curves for Maze Road Bridge developed by the USACE (2002).

Because of the potential for breaks in the slope of the water surface profile between the three component properties forming the project site, as well as between the site and the river, we recommend monitoring water surface elevations at the following locations to establish the profile across the site and its relationship to the river:
1.   San Joaquin River, at the upstream end of project site
2.   San Joaquin River, at the downstream end of project site
3.   At the upstream end of Lara
4.   At the downstream end of Lara
5.   At the upstream end of Hagemann
6.   At the downstream end of Hagemann
7.   At the upstream end of Vierra
8.   At the downstream end of Vierra

Low points on the floodplain should be chosen to allow stage monitoring there to serve as an indicator of floodplain flows, to be corroborated by river stage monitoring. If desired, additional monitoring points near the breaches but out of the primary flow path (e.g., somewhat upstream or downstream the adjacent levee) could be attempted to further confirm levee breach flows as the source of floodplain inundation, but these may be subject to failure due to high flows. These data loggers would need to be checked and data downloaded approximately monthly throughout the rainy season.

High velocities are not anticipated to be an area of specific concern related to habitat concerns, based on modeling results. Thus, potential problems associated with high velocities would be limited to infrastructure erosion concerns, and could be evaluated based on dry season evaluation of conditions. In the event that erosion of concern occurred, it could likely be addressed without need for direct measurement of velocities. Given these considerations, no specific monitoring of erosion conditions is included in this plan.

Excessively low velocities may be a concern if they are associated with an absence of flow cues for fish on the floodplain, and thereby result in stranding. Rather than attempting to measure low velocities directly, which would be difficult to accomplish and only of indirect value, we recommend that evidence of significant fish stranding be used to indicate whether the absence of significant flow cues is a problem. If monitoring of fish conditions during the first 5 years of the project indicates this to be the case, collection of velocity data prior to adaptive management measures should allow assessment as to whether an altered velocity regime is associated with improvement in the problem.

Velocities may be associated with evaluation of habitat conditions used by different fish for various purposes; because these conditions and their use would be transient, any monitoring for this purpose should be directed, and probably conducted, by those monitoring fish use of different floodplain areas.

Flow patterns at the project site should be evaluated through the use of aerial and field inspection during and after inundation events. It may be possible to discern flow patterns as a result of visible sediment differences or surface irregularities in moving water, even in low elevation oblique photographs or video recordings. On the ground observations may be even more revealing of flow patterns, but may be more difficult during a flood event given limited observation locations. It would be desirable to obtain observations on both the rising and falling limb of a flood, as the flow patterns are likely to be different during these two periods. We recommend that both aerial and ground observations be conducted during the rising and falling limbs of a hydrograph at least once, and that a determination be made at that time whether subsequent observations use both methods. Observations should be recorded and documented in photographs and/or videographic recordings. Such observations should be conducted during at least two separate flood events, and the results assessed for the indication of need for modification to the site to better meet habitat goals or to address potential maintenance issues.

Ponding conditions at the site following the disconnection of the site from the river should be evaluated twice a year for the first five years of site inundation, either through aerial or field observation. On the basis of the first five years of observation and the site evolution observed, a determination can be made as to whether additional ponding monitoring is appropriate. Ponds should be documented and identified as potential problem ponding areas if ponding areas, other than the three ponds that comprise White Lake, are identified no later than June 1 (when reconnection is extremely unlikely) or within two weeks of pond disconnection from the river if later. The location, areal extent, and maximum depth of each should be measured (aerial methods acceptable for the first two parameters; field measurement is required for the last unless the ponds have drained) upon initial identification and then again eight to twelve weeks later. The second measure would be used to evaluate persistence. These observations would help to identify potential problem locations for stranding evaluation or, under extreme conditions, for providing additional

habitat area for predatory fish. Evaluation of these ponds for stranding, predatory fish habitat, or other concerns would happen under the auspices of biological monitoring. Adaptive management measures, such as grading or revised management of planned wetland areas, should be considered if habitat concerns related to ponding are identified by project biologists.

7.1.1.2 Surface Water Quality

Temperature monitoring equipment should be installed at each of the stage data loggers identified in Section 7.1.1.1, above, and monitored throughout the inundation season for the first 10 years of project operation. As previously indicated, these data loggers would need to be checked and data downloaded, approximately monthly throughout the rainy season.

7.1.1.3 Groundwater

The depth to groundwater below the ground surface should be established by installation of five to six peizometers penetrating the shallow groundwater table to a depth of at least 20 feet. This depth exceeds the rooting depth of mature cottonwoods and should be sufficient to establish habitat conditions associated with groundwater. One peizometer should be installed on Lara, one on Vierra, and three on Hagemann. Of the three on Hagemann, two should be near the levees at approximately the same distance from the centerline of the wetlands comprising White Lake and the third should fall between these two locations and be located closer to the wetland. Each peizometer should be located within an area that would be only shallowly flooded except during a very large flood event. The peizometers should be capped and sealed at the surface to minimize direct inflow to the monitoring well, and should extend far enough above the ground surface to minimize the chance of burial by sediments (e.g., 1 foot). The lip of the well and the adjacent ground surface should be surveyed in to establish a vertical reference once the peizometers are installed. Both absolute elevation and depth below ground surface of the water level should be derived from monthly monitoring of water depth below the lip of the well year-round for the first three years. The need for additional monitoring should be evaluated at that time.

7.1.2   Site Evolution

Physical parameters associated with evolution of the site include the following:

1. Floodplain topography
2. Breach geometry

The recommended monitoring of both of these parameters is described below.

A pre-project description of floodplain topography has been developed as part of the project planning process. Although it does not include details of minor site features, such as ditch geometry, it provides a

good basis for evaluation of changes to the floodplain that will occur as a result of floodplain inundation and drainage processes. In addition, it does not include all anticipated changes to floodplain topography prior to floodplain inundation. Planned changes include modification for the seasonal wetland project being constructed by the SJRNWR, as well as the project levee breaches. Additional changes may also have already occurred that are not reflected in the current pre-project description of floodplain topography, but these are anticipated to be inconsequential for the purposes of monitoring changes in floodplain topography.

It is probably reasonable to assume for purposes of establishing baseline floodplain conditions that the wetland and levee breaches will be generally constructed according to the design plans. However, it is reasonable to assume that most change will occur in the vicinity of the major flow paths of the project – i.e., in the vicinity of the breaches in the project levees and through the West Stanislaus Canal and Hospital Creek. Thus, for purposes of providing better baseline data, cross sections in these locations should be established following construction and prior to the first inundation event.

A cross section at each levee breach should be surveyed prior to the initial inundation. In addition, at least three monumented cross sections should be established and surveyed on the project site side of each levee breach over a width of approximately 2000 – 3000 feet along the expected flow line or levee to levee (on Vierra, where the same cross sections can monitor both breaches) and distances of approximately 300, 800, and 1500 feet.

In addition, connections through the West Stanislaus Canal and Hospital Creek will be important routes for the passage of flooding and drainage waters, whether such connections are constructed or merely potential. Therefore, surveying of at least two cross sections along Hospital Creek and three along the longer West Stanislaus Canal above and below the connections to the floodplain should also be conducted prior to the first inundation event.

It is reasonable to expect that trends in floodplain topographic change will occur in the early years of the project. Because changes to topography will be episodic but only capable of being surveyed during the dry season, these cross sections should be re-surveyed annually using field methods for the first five years of the project and then at least once more after ten years of inundation opportunity have occurred.

If any other areas of significant topographic change (e.g., capable of redirecting flow paths or changing flow quantities, or capable of affecting habitat conditions significantly) are observed, we recommend that monumented cross sections capable of describing that change also be established as quickly as possible for addition to the annual monitoring program. The pre-project floodplain topographic description will in that case serve as the approximate initial conditions description.

In addition to annual field surveys, we recommend that aerial photography of the site and the adjoining San Joaquin River corridor be conducted at five-year intervals for at least the first 10 years of the project life and at 10-year intervals for the following 40 years. Ideally, especially for the first set of images, the photographs would be orthorectified. That would provide a basis for future comparison, should

documentation of aerial changes be desired and warrant future orthorectified imagery. The images should be flown at a level appropriate for the multiple uses to which they will be put; for purposes of delineating broad changes in site evolution, 1 inch : 2500 feet (1:30,000) is probably adequate. Finer detail will allow greater resolution of changes, though vegetative growth may soon obscure significant amounts of landscape change as time goes by.

7.2   MONITORING TASKS AND EXPECTED COSTS

The monitoring tasks described in Section 7.1 are summarized in Table 7-1 below.

The costs of the outlined monitoring program are based on estimated commercial costs for planning purposes. Direct costs may be significantly less if labor and equipment is available through a university or agency contribution. As scoped, we estimate the costs of this monitoring program to be approximately $60,000 - $130,000/year for the first 10 years, and $0 - $27,000 each year thereafter, or an average annual cost over a 50-year monitoring lifespan of approximately $20,500/year or $1,000,000 total. The proposed monitoring program calls for more intensive monitoring during the first few years of site establishment (3 – 10 years) and then periodic "snapshots" of topographic and planform conditions at 10-year intervals.

Part of the difficulty in monitoring such a project is that floodplain inundation may occur 10 times or perhaps only 1 time in 10 years. Thus, we have presumed more intensive monitoring to be required for at least a 10-year period to ensure that some relevant data collection will occur.

In the event that it is determined that monitoring costs must be substantially less, we recommend installation of depth and area gauges for only 5 years, only a single flow pattern evaluation, and deletion of temperature and groundwater monitoring completely, unless either is demonstrated to be a potentially significant issue. In this scaled-back version of physical processes monitoring, we estimate the costs at $65,000 - $103,000/year for the first 5 years and $0 - $27,000/year for each year thereafter, or an average annual cost over a 50-year monitoring lifespan of approximately $12,000/year or $606,000 total. If even this reduced monitoring program is not viable, then a system of ground observations with staff gauges and intensive on-the-ground observation and data recording during flooding events, combined with analysis, may provide a basic understanding of the inundation characteristics of the project site, while the site evolution surveying and aerial photography would provide a long-term record of broad changes at the site. Specific detailed monitoring of physical conditions over this large a site would not be possible at modest cost.

7.3   STORAGE, REPORTING AND USE OF MONITORING DATA

Monitoring data will be useful for at least two purposes. First, it will provide a record that can be used by the SJRNWR or other researchers to learn about post-project conditions and site evolution, so as to benefit planning for other floodplain restoration projects, especially in the vicinity of this project. Secondly, its use will be critical to any adaptive management activities. However, to be useful for adaptive management, it is essential that this data be both documented *and* interpreted for significance in light of the project as a whole. Only with an integrative interpretation can the significance of the findings and appropriate responsive actions be recommended and designed. This interpretation must integrate physical processes, ecological function and institutional considerations to be effective.

For utility, monitoring data should ideally be stored in an Access/GIS database and reports of findings generated annually. Annual reports would ideally contain key data or descriptions of the key data collected, sufficient to provide a basis for findings presented. Reports should assess of the success of the project in meeting floodplain-dependent habitat goals, identifying potential problem areas, and recommending management actions that are responsive to the collected data and further the goals of the project. Reporting costs have been included in the costs described in Section 7.2 and Table 7-1.

Table 7-1 Summary of recommended monitoring for physical processes

Monitoring parameter	Goal	Frequency	Duration	Cost	Method/data collected
Surface water flow					
Depth and area	Characterize depth and areal extent of floodplain flows across site relative to known flow-frequency relationships, floodplain topography	Continuous monitoring	At least 10 years	$46,000/ year	Use pressure transducers or similar to collect continuous stage data in the San Joaquin River adjacent to the project site and across the project site (≥8 locations total).
Duration	Characterize duration of flood flows	Continuous monitoring	At least 10 years	$4,000/ year	(Derive from depth and area data collection.)
Timing	Characterize timing of flood flows	Continuous monitoring	At least 10 years	$1,000/ year	(Derive from depth and area data collection.)
Velocity	Monitor for conditions of concern (e.g., erosion of infrastructure, stranding hazards due to lack of flow cues)	N/A	N/A	N/A	Monitor only in the event of incidental reporting of conditions of concern.
Flow patterns	Broadly identify the movement patterns during inundation events on the rising and falling limbs of the hydrograph	At least 2 flood events in 10 years	At least 10 years	$10,500/ flood event	Both aerial and ground observations on the rising and falling limb, documented in photographic or videographic media and written description.
Ponding	Identify ponding areas that are potentially problematic in terms of habitat concerns	Annually	At least 5 years	$14,000/ year	Observation at the end of each inundation season together with the collection of location, depth and aerial extent of ponding data; repeat survey 8-12 weeks later.

Table 7-1 Summary of recommended monitoring for physical processes *(continued)*

Monitoring parameter	Goal	Frequency	Duration	Cost	Method/data collected
Groundwater					
Level	Identify the depth to groundwater across the site	Monthly during dry season	At least 5 years	$17,000/ year (well installation cost distributed over 3 years)	Measurement of depth to groundwater and absolute elevation at ≥ 5 locations across the project site.
Surface water quality					
Temperature	Characterize the temperature of floodplain flows	Continuously, reported annually	At least 10 years	$10,000/ year	Combine temperature monitoring equipment with stage recording installations (≥8 locations total).
Site evolution					
Floodplain topography and breach geometry	Characterize evolution of the floodplain	Annually the first 5 years, then at 10 years and then each 10 years thereafter	At least 50 years	$27,000/ year (initially annual; later at intervals)	1. Field survey cross sections at and adjacent to breaches (≥28 locations total). 2. Conduct aerial photography of site at 1:30,000 or better; initial imagery, at least, should be orthorectified.

8. OPPORTUNITIES FOR APPLICATIONS OF HYDRAULIC MODEL TO ADAPTIVE MANAGEMENT / MONITORING

A detailed 1D/2D coupled model has been constructed as a result of Phases 1 and 2 of this study. While the results produced by this model have been useful for the assessment of the proposed levee breaching project on anadromous fish habitat benefits, PWA believe that the model has good potential to become a valuable tool for prediction of site evolution, adaptive management testing, and flood mapping. Potential uses of the model for monitoring and adaptive management purposes could include the following:

1. With collection of additional sediment data, the model could be used to predict the trajectory of site evolution and the effectiveness of the site as a trap for fine sediments.
2. Key data for final design and mapping of floodplain inundation during key flood events (e.g., 100-year) could be developed through simulation with a revised hydrograph.
3. The model could be extremely useful to test the sensitivity and response of the project to test the sensitivity of the project to potential adaptive management measures.

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Appendix A

USFWS Conceptual Wetland Design

SCHEMATIC CROSS-SECTION VIEWS OF SEASONAL BASINS DEPICTING AREAS OF PROPOSED DIRT EXCAVATION AROUND PERIMETERS OF BASINS

SEASONAL BASIN A (MAP # 1)

Excavation would be done by earth moving scrapers starting at the perimeter of the basin (32-ft elevational contour), angling downward for a cut of 6 inches and moving towards the center of the basin until it daylights out at the 31.5-ft contour

SEASONAL BENCH ON SOUTH END OF LOWER WHITE LAKE (MAP # 2)

Excavation would be done by earth moving scrapers starting at the perimeter of the basin (30.5-ft elevational contour), angling downward for a cut of 6 inches and moving towards the center of the basin until it daylights out at the 30.5-ft contour

GENERAL

As depicted on the larger PWA/DU topographic map, dirt excavation would be done only along portions of the wetland basin perimeters.

Most of the excavated dirt would be wasted throughout the uplands adjacent to the wetland basins. Those uplands will subsequently be disked and furrowed as part of field preparation for the riparian restoration planting. Because of those actions, there will be no measurable change in the existing upland (floodplain) topography due to moving dirt out of the wetland basins.

Part of the excavated dirt would be used to create several small islands within the basins (exact number and locations not yet determined, but no more than 3 or 4 per basin). These would be a combination of small circular islands (approx. 20-ft dia.) or small linear islands (up to 40 x 15-ft) oriented in a northerly direction (parallel to anticipated flood flows). Islands would extend no more than 1-foot above the full flood-up water surface level of the individual basins under the managed regime.

Question: Given that the 1-ft contour PWA/DU topographic map is being used as the base to model flows across the floodplain, would the excavation of 6 inches of dirt within parts of single 1-ft elevational increments (contour lines) affect the results of the modeling?

removed), into Lower White Lake and continue northward to the breaches. If desired by fisheries personnel or for some other hydrological purposes (and river level allowed) the screw gate structure at the terminus of the Main Drain could be opened to allow part of the water to gravity flow into the river from that point. As waters of the San Joaquin River receded to pre-flood levels, Seasonal Basin A would be allowed drain completely dry to avoid any fish entrapment. However, the basin could be kept flooded (by putting boards back in the structure) if desired by fisheries biologists to provide rearing habitat for anadromous fish, and later drained so fish move into the river.

Lower White Lake:

Non-Flood Year, Managed Regime - The center of this wetland complex would kept flooded year round, and the seasonal benches on the north and south flooded during November through May. Water would be supplied by agricultural tailwater from upslope farm operations and from lift pumps at the WSID intake canal (especially during winter) delivered via existing field ditches. Water levels would be kept at the 29-ft elevation level during the summer and early fall, and then raised to the 30.5-ft level to flood up the adjacent seasonal benches. Water levels would be controlled by the outlet structure on the northeast side of the basin along the Main Drain. The outlet structure could be used to completely drain Lower White Lake if necessary for management purposes. Water passing through the outlet structure would flow down the Main Drain to the structure at its terminus, and into the San Joaquin River via gravity flow.

Flood Year - Lower White Lake would become inundated above the managed water level as floodwaters backed into the area from breaches to the north and/or east of the basin. As water levels in the river receded the floodwaters would drain back through the breaches and out of Lower White Lake and the rest of the floodplain. The screw-gate would be left open and boards removed from the outlet structure to facilitate flows through the lake and the Main Drain toward the breaches. Because the center of Lower White Lake is lowest part of the floodplain(except for the drainage ditches in the bottom of the lake), it is likely that some water will remain impounded in the basin after the floodwaters have flowed out the breaches. As waters in the river recede to pre-flood levels, Lower White Lake could be drained completely dry to avoid fish entrapment by passing water through the outlet structure, down the Main Drain and into the river via gravity flow. However, the basin could be kept flooded (by putting boards back in the structure) if desired by fisheries biologists to provide rearing habitat for anadromous fish, and later drained so fish move into the river.

Seasonal Basin B / Seasonal Basin C:

Because these basins will not be restored as part of the current CalFed grant, management strategies are not as far along in development as the other basins. In general, they will function similar to Seasonal Basin A. Water will be delivered via a combination ag tailwater drainage and lift pumps. The basins would be flooded during November through May with summer irrigations if necessary. Both would be able to be drained completely dry through outlet structures on the north ends of the basins into the San Joaquin River. Floodwaters would flow into and out of the sites from breaches north of the basins. As floodwaters recede, the basins could be allowed to drain completely, or kept flooded temporarily for fisheries management purposes.

PROPOSED WETLANDS MANAGEMENT

Maintenance of wetlands within the West Unit floodplain on most years will require water being taken from the San Joaquin River via lift pumps. The FWS acquired numerous lift pumps along the river and WSID intake canal, and the riparian rights associated with the properties when it purchased these lands. The lift pumps necessary to provide water to the restored wetlands will be renovated and fitted with approved fish screens so that Refuge can manage those wetlands during non-flood years. Prior to management of the restored wetlands, Refuge and Fisheries Office staff need to jointly prepare an operations plan that will direct water management in the West Unit during and following flood events that inundate the floodplain.

Upper White Lake:

Non-Flood Year, Managed Regime - The wetlands would remain flooded throughout most of the year with a draw-down in late August and subsequent flood-up in November. Water would be provided by drainage from upslope agricultural operations and a lift pump on the WSID intake canal. Water levels would be controlled though a stop-log water control structure at the outlet of the wetland basin. Drainage would be provided by an existing field drain (modified as part of the restoration) would flow from the outlet structure to the WSID intake canal.

Flood Year - Non-structural flood control alternatives presented to date do not indicate the Upper White Lake area would receive floodwaters from constructed levee breaches. However, based on past observations, the amount of area flooded there does increase during high water events, and it is likely the area would become inundated by floodwaters during a major flood which results in levee failure. In such event, drainage would be provided after the river levels drop via the Upper White Lake outlet into the WSID intake canal. If necessary, the entire wetland basin could be drained to avoid any fish entrapment.

Seasonal Basin A:

Non-Flood Year, Managed Regime - The wetland would be flooded during November to May, with periodic irrigations, if necessary, during the summer to promote the growth of moist soil plants in the basin and trees that become established around the perimeter. Water would be provided by lift pumps on the WSID intake canal and delivered to the wetland basin via existing field ditches. The water level would be controlled by the outlet structure (stop-log water control structure) on the north end of the wetland basin. Drainage from the wetland would flow from the outlet structure down the Main Drain to the structure at its terminus and ultimately into the San Joaquin River.

Flood Year - The basin would become inundated above managed levels by floodwaters backing into the area from breaches north of the site (or directly from the WSID intake canal if it is decided, as part of the non-structural flood control alternative analysis, to breach the canal). As water levels in the river dropped, water in this part of the floodplain would follow the elevational gradient and flow toward the breeches. Receding water within the wetland basin would sheet flow northward until it hit the 33 foot elevation (height of the berm across the north end of the seasonal wetland basin). At that point, water would flow toward the low flow channel of the basin and through the outlet structure (all boards removed). Water would gravity flow down the Main Drain and through the outlet structure of Lower White Lake (again all boards

(top elevation 33 ft.) Curved and offset slightly to the north. This then, would form the northwest boundary of the wetland and separate the unit from the adjacent White Lake.

Lower White Lake (permanent with seasonal benches): This existing wetland is on the former Hagemann property and was formed in summer 2000 when part of the agricultural tailwater draining through the Refuge was held back rather than being completely passed on to the river, thus allowing the lower parts of the fields to flood. Size and shape of White Lake change dramatically based on what height the water level is held. The Refuge proposes to develop this wetlands so that there is a 220-acre permanent wetlands in the center (field H 14 and part of H 15 - deepest part of the basin) with seasonal benches (higher elevation ground) on the north (fields H 11 and 12) and southwest (field H 15 [part]) totaling 100 acres. The permanent wetlands could be maintained by keeping water at the 29 foot elevation, and the adjacent seasonal benches flooded (and the permanent wetlands made deeper) simply by increasing water surface height to the 30.5 foot elevation. Restoration work for this wetland complex would require draining White Lake during the year in which the construction was done to allow access by heavy equipment (after the agricultural irrigation season and before the onset of winter rains). A number of drainage ditches (actually under water during full flood-up) and their associated spoil banks would be bulldozed down to ground level. Any drain ditches necessary to allow drainage from upslope farmers would be retained. Where possible, any associated spoil banks would be removed or re-contoured into islands. On the seasonal benches, earth movers would be used on part of the perimeter to lower the 30.5 foot contour to 30 foot in a manner similar to that described for Seasonal Basin A. A 36-inch water control structure (combination stop log and screw gate) would be installed at the confluence of a major drainage ditch in the permanent wetlands and the Main Drain. This would provide the point of control where water levels could be regulated, and water from upslope drainers conveyed through the Main Drain and into the river (the rest of the lake is separated from the Main Drain by existing canal banks). This outlet structure would also have the capability of draining Lower White Lake completely dry if necessary.

Seasonal Basin B: This proposed wetland would be on the former Vierra property and extend across the floodplain in a northwest direction from the levee at Hospital Creek to the levee along the San Joaquin River (parts of fields V4,V5, V6, and V7). Detailed planning of this wetlands restoration has not been done because this work is not part of the current CalFed grant, but will be done in the next subsequent phase (next grant request. Tentative plans call for using part of an existing field drain leading to the San Joaquin River to provide drainage for the wetland, and managing the water surface level at the 28 foot elevation..

Seasonal Basin C: This proposed wetland would be on the former Vierra property and extend across the floodplain in a northwest direction from the levee (which may be breached) separating fields V3 and V4. to the north boundary of the Refuge along the San Joaquin River (parts of fields V1, V2, and V3). Detailed planning of this wetlands restoration has not been done because this work is not part of the current CalFed grant, but will be done in the next subsequent phase (next grant request. In addition, better topographic mapping needs to be developed. Tentative plans would entail having the western third of the fields flooded with drainage toward the San Joaquin River.

than draining off all upslope tailwater and keeping the former Hagemann fields dry, that part of that water could be allowed to flood the lower portion of the fields (thus recreating the historic Lower White Lake) without impacting upslope drainage. A staff gauge was installed by the drain pump and a water level determined in which Lower White Lake could be maintained, and the water surface would still be lower than the elevations of the upslope drainage pipes and ditches that conveyed ag tailwater onto the Refuge. A 36-inch water control structure with a screw-gate was installed beside the existing drain pump to allow conveyance of the ag tailwater by gravity flow, better manage water levels, and to avoid using the drain pump. Lower White Lake has been maintained as a permanent wetlands since summer 2000 (water surface elevation ranging by season from 29 to 31 ft.). Emergent stands of cattail and roundstem bulrush became established within one year, and waterbirds; including waterfowl, shorebirds, herons, sandhill cranes, white pelicans, cormorants, Caspian terns, and white-faced ibis; quickly began using the wetlands.

PROPOSED WETLANDS RESTORATION

Upper White Lake (semipermanent): This wetlands would be located on the southwest side of the former Lara property, and consist of fields L2, and portions of L3 and L4 (as labeled in the Sacramento River Partners Pre-Restoration Plan - see attachment). The site is shown as a historic wetland on old USGS maps and labeled as Upper White Lake. Much of field L2 remains flooded most of the year due to drainage from upslope farming operations. There is a series of 6 small rectangular ponds connected by spoil bank levees, which were apparently the remnants of an abandoned fish farming operation, in the lowest part of field L2. Wetlands restoration would consist of using earth moving equipment to remove the spoil bank levees and shape the lowest part of field L2 and parts of fields L3 and L4 into a basin. The resultant 30-acre wetland would be linear in shape with its southern shoreline adjacent to the natural levee that defines the edge of the floodplain. The wetland would drain through an existing field drainage ditch northward to the WSID intake canal. (Topographic data of wetland basin and managed pond surface elevation will be determined when previous topographic map is corrected).

Seasonal Basin A: This wetland would be located on the former Hagemann property and extend from the WSI intake canal in a northwest direction to Lower White Lake. It would consist of portions of fields H1, H2A, H17, H18, and H15, and total 125 acres. The overall shape and size of the basin will be defined by the existing topography (the fields were leveled, and slope for irrigation purposes toward a central drainage ditch [Main Drain]) with a managed flood up level generally following the 32 foot contour (see map). Scrapers would be used to lower the ground elevation approximately 0.5 ft. along the 32 foot contour going out towards the 31 foot contour (in most places, dirt removal to the 31.5 foot contour would daylight out within 50 - 100 yards of the 32 foot contour). The excess dirt would be used to create islands (top elevation 33 foot) within the basin or wasted throughout the adjacent uplands. The part of the Main Drain within the basin would be utilized as the lowest portion of the wetland (and to provide a low flow channel to the outlet). A 36-inch outlet structure (combination stop log and screw gate) would be installed at the Main Drain on the north end of the wetland unit. The basin could be independently drained through that structure into the Main Drain. On the northwest side of the basin, a drainage ditch with a high spoil bank (which if not removed would form the northwest boundary of the wetland) would be bulldozed in to ground level and replaced with lower berm

PROPOSED WETLANDS RESTORATION
ON WEST UNIT OF SAN JOAQUIN RIVER NWR
(Former Hagemann, Vierra, and Lara Properties)

RESTORATION AND MANAGEMENT PHILOSOPHY

The Refuge desires to restore wetlands that would be managed to benefit wetlands dependent wildlife and wetland communities during non-flood years (majority of years), but yet be designed so that these wetlands would facilitate flood flows across the floodplain and through designed levee breaches, provide rearing benefits for anadromous fish, and minimize potential for fish stranding. Location and shape of the wetlands are driven by topography, presence of hydric soils, and the actual location of the wetlands documented on old aerial photography taken prior to leveling and ditching for agricultural development. The wetlands would recreate the historic Upper and Lower White Lakes and, when fully flooded, form a contiguous band of seasonal and permanent wetlands across the lowest portion of the West Unit floodplain.
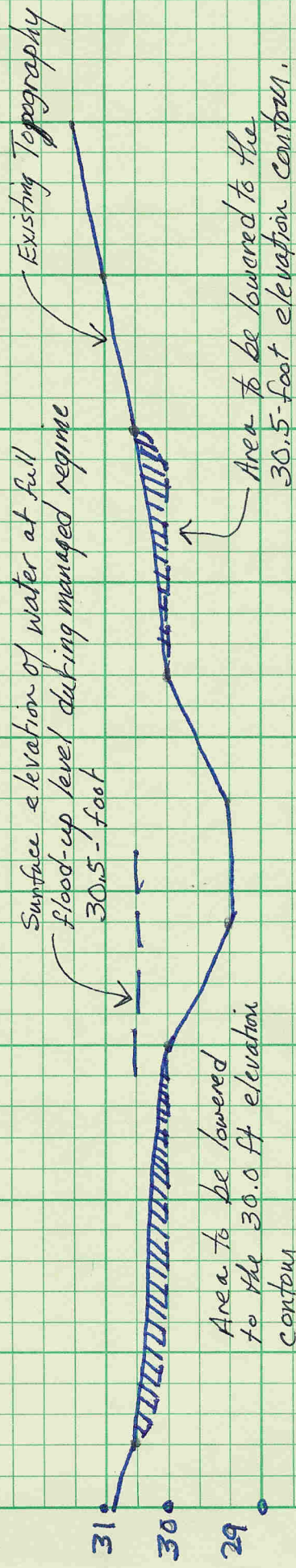
PRIOR CONDITIONS AND EXISTING SITUATION

Before the Refuge acquired these lands, they were divided up into a collection of fields and intensively farmed on an annual basis. These fields had a network of both pipelines and open delivery ditches to convey irrigation water to the fields and field drains to move tailwater. Also, there was also a network of main collector drains and toe drains to drain off the agricultural tailwater and lower the overall groundwater table. In the short term, the Refuge and its contractor will use the delivery facilities and field drains to irrigate plantings as part of the riparian forest restoration. As the plant communities develop and no longer need irrigation, many of these ditches will be eliminated. However, the Refuge plans to keep and maintain some ditches and pipelines for use as water delivery systems and drains for the managed wetlands.

In addition, the Service has a legal obligation to upslope landowners to provide drainage of agricultural tailwater across Refuge lands to the San Joaquin River. The former owners of the Hagemann property had a long-standing legal agreement with the White Lake Mutual Water Association (upslope farmers) to convey the upslope agricultural tailwater across that property. The drainage infrastructure consists of a collector drain at the west side of the Refuge boundary (edge of the floodplain) and various drain ditches that lead to a drain pump that pumps into the San Joaquin River. The West Stanislaus Irrigation District (WSID)also has a legal right to convey agricultural tailwater from upslope lands across the former Vierra property via Hospital and Ingram Creeks to the San Joaquin River. The Service, upon acquiring these properties, inherited the legal obligation to continue to provide drainage for those upslope farmers across Refuge lands. If the Refuge took actions that impaired drainage for those upslope landowers, the Service would end up in litigation.......and would undoubtedly lose. Consequently, the ditches and other facilities necessary to meet the Service's legal drainage obligations must be maintained in operational order.

Following acquisition of these lands in late 1999 and early 2000, it was determined that, rather

Schematic Cross-Section View of Southern Seasonal Bench of Lower White

Lake to be Lowered to the 30.0 foot Elevation

#2

Existing Topography

Surface elevation of water at full flood-up level during managed regime 30.5-foot

Area to be lowered to the 30.5-foot elevation contour.

Area to be lowered to the 30.0 ft elevation contour

31
30
29

Not to Scale. Actual proportional width of basin is greater than depicted on this schematic view.

Schematic Cross-Section View of Seasonal Basin A showing Areas at Perimiter

of Basin to be Lowered to 31.5-Foot Elevation

#1

Existing Topography

Surface elevation of water at Full floading level during managed regime ≅ 32.0-feet

Area to be lowered to the 31.5 foot elevation contour

Area to be lowered to the 31.5 foot elevation contour

Existing raised roadway to be removed

Existing drainage ditch will be in center of basin - allow complet drainage

32

31

30
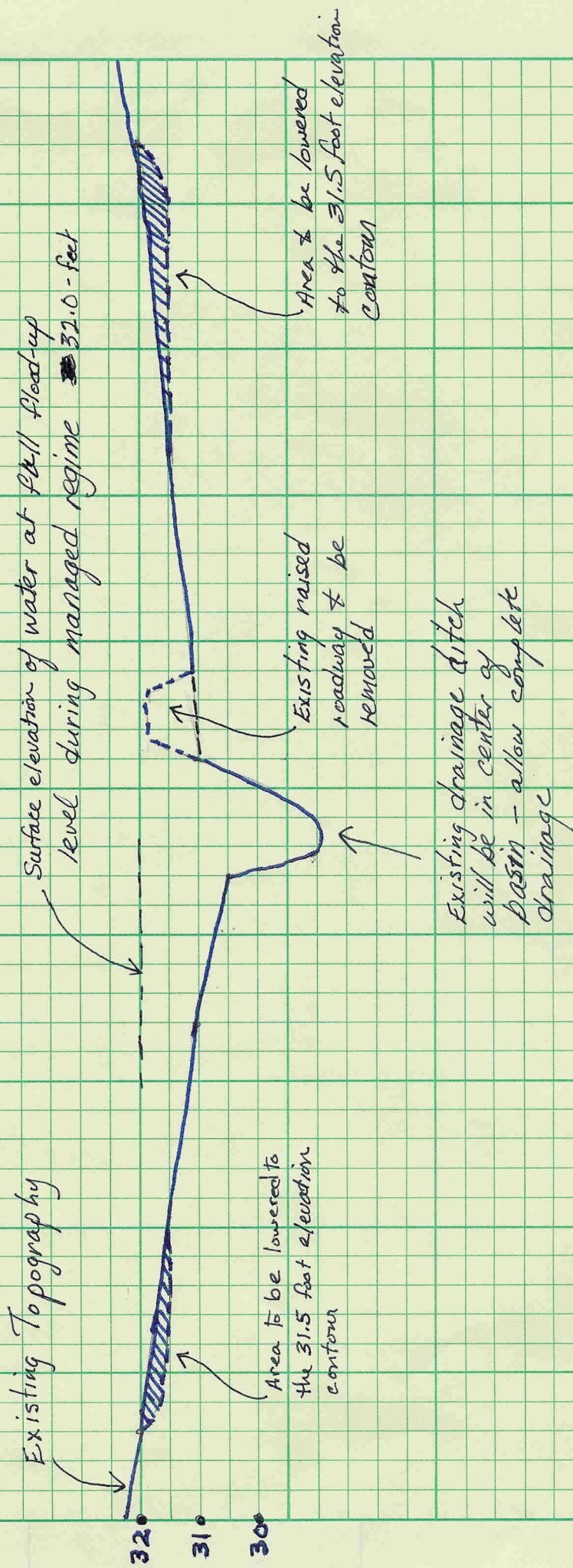
Actual width of basin is greater then depicted on this schematic view.

Figure 4

San Joaquin River NWR
West Units
Existing Vegetation

Hwy. 132

Paradise Rd.

Finnegan's
Cut

Toulumne River

San Joaquin River

V1
V2
V3
V4
V7
V5
V6

Seasonal
Basin
C

Seasonal
Basin B

Hospital Creek

North
Seasonal
Bench

Lower
White Lake
(perm)

South
Seasonal
Bench

River Rd.

Seasonal Basin A

H11
H12
H20
H14
H21
H24
H25
H23
H22
H18
H15
H17
H2 A
H1
L1
L3
L4
L5
L6
L8
L7
L9
L11

Upper
White
Lake

Project Boundary
irrigated pasture
native pasture
cropland
riparian
permanent wetland
semipermanent wetland
seasonal wetland
vernal pool
residential
dairy

2000   0   2000 Feet

N

Prepared by:
Geographical Information Center
November 23, 1999

Proposed or Existing Wetland

H17 - Field Number